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CONDUCTIVITY OF MERCURY.

By CAPTAIN JOHN ERICSSON.

From "Nature."

It was shown in a previous article* that solar intensity cannot be accurately ascertained by the thermoheliometer employed by Père Secchi, owing, among other causes, to the imperfect conductivity of the mercury in the bulb exposed to the sun. Meteorologists, however, do not generally accept the assumption that the conducting power of mercury is so imperfect as to affect materially the correctness of the indication of mercurial thermometers, Deschanel being quoted in support of the opinion that mercury is not an imperfect conductor. We are reminded that Prof. Everett, in a recent translation of the works of the author mentioned, assumes that the conductivity of quicksilver in the bulb of a thermometer is the same as a vessel "with thin metallic sides containing water which is stirred" (see Prof. Everett's translation of "Deschanel's Natural Philosophy," Part II., pp 245–387). The subject is so intimately connected with the determination of solar temperature and solar energy, that it has become indispensable to settle the question by some thorough practical test. Accordingly an apparatus, represented by the accompanying illustration has been constructed by the writer to ascertain the conductivity of mercury. Before entering on a description, it will be instructive to point out that the heat communicated to the bulb of a thermometer by solar radiation is transmitted to its contents chiefly by convection, hence that the altitude of the sun during the observation influences the accuracy of the indication. This will be readily comprehended. Fig. 2 represents the bulb of a thermometer exposed to the rays when the sun's zenith distance is 65 deg.; Fig. 3 representing the bulb when the zenith distance is 18 deg. 23 min., the latter being the minimum at the observatory of the Roman College, where the thermoheliometer has been long employed for the purpose of ascertaining the intensity of solar radiation. Referring to Fig. 2, it will be seen that the blank crescent, *c*, whose varying thickness indicates very nearly the amount of heat imparted at each point of the spherical surface presented towards the sun, occupies an almost vertical position. The mercury contained within the space indicated by the said crescent, having its specific gravity reduced by the radiant heat, will ascend; while the mercury on the opposite side, which retains its specific gravity, will descend; thus a circulation will be established by means of which the heat received from the sun will be gradually communicated to the entire mass of mercury in the bulb. But, when the latter is exposed to the sun's rays under a zenith distance of about 18 deg., as shown in Fig. 3, the heated mass of mercury contained within the crescent, *a*, has so slight an inclination that scarcely any circulation takes place. Con-

* See Magazine Vol. VI., p. 499.

sequently, if it can be shown practically that mercury is incapable of transmitting heat from particle to particle with sufficient velocity, it will be evident that thermometers and thermoheliometers with spherical bulbs are worthless as means of measuring the intensity of solar radiation. It will be perceived that if the bulb in Fig. 3 be surrounded by an enclosure, as in the thermoheliometer, the mercury contained within the space indicated by the crescent, *b*, will radiate far less heat towards such enclosure than the mercury within the opposite heated crescent, *a*. It will also be perceived that by increasing the size of the bulb, the transmission of heat from *a* to *b* will be retarded unless the conductivity of mercury be perfect. Hence the *size* of the bulb is an element affecting the accuracy of the indication —a circumstance fatal to the employment of a spherical bulb in the thermoheliometer.

Fig. 3

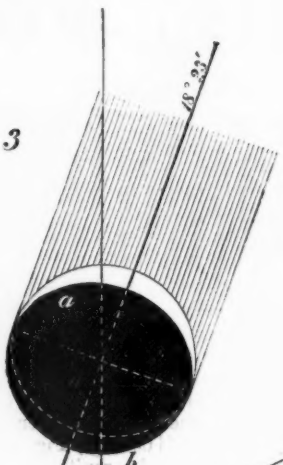
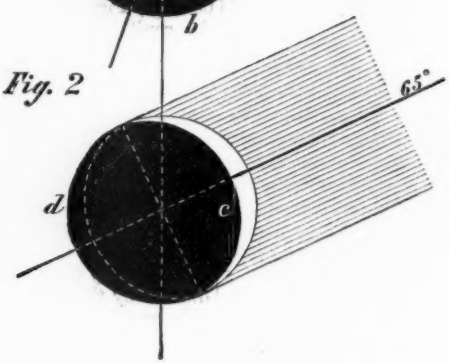


Fig. 2



The nature of the illustrated apparatus constructed for the determination of the conductivity of mercury will be readily understood from the following description :— Fig. 1 (frontispiece) represents a longitudinal section through the vertical plane. *a* is a boiler, with a flat bottom and semicircular ends, supported on two columns, *f* and *g*, resting on the bottom of the cisterns, *c* and *d*. The column, *f*, is composed of wrought copper plated with silver, highly polished. The column, *g*, consists of a cylindrical vessel of glass open at the top, filled with mercury, and surrounded with a socket, *h*, composed of polished silver. The cisterns, *c* and *d*, supported on non-conducting substances, are plated with polished silver, and provided with funnel-shaped open-

ings at the top, through which thermometers are inserted. These cisterns, as well as the columns, *f* and *g*, are surrounded with non-conducting coverings, *p*, *p* and *o*, *o*. A lamp, *b*, is applied between the cisterns for heating the water in the boiler. It is scarcely necessary to observe that the polished silver plating of the copper column, and the polished silver socket round the mercurial column, are intended to prevent loss of heat by radiation, while the coverings before mentioned are intended to prevent loss of heat by convection attending atmospheric currents. The inside diameter of the cylindrical vessel, *g*, it should be noticed, is 0.5 in., corresponding exactly with the diameter of the copper column, *f*, the top of which is on a level with that of the mercurial column. The lines, *k l* and *m n*, are in the same horizontal plane, their distance below the upper ends of the columns, *f* and *g*, being precisely 2 in.

The object of the apparatus being that of comparing the conductivity of mercury to that of some other metal, *copper* has been selected, as its conducting property is better known than that of any other. The leading feature of the arrangement will be comprehended by a mere glance at the illustration. An equal amount of heat being applied to each column, it is intended to show by the elevation of the temperature of the water in the cisterns, *c* and *d*, what relation exists between the conductivity of mercury and copper. Regarding the application of the heat, it will be evident that an equal amount must infallibly be imparted to each column if the lamp be sufficiently powerful to keep the water in a state of continuous ebullition. Obviously the heat from the lamp, if urged, will cause a rapid upward motion of the water in the middle of the boiler, and a correspondingly rapid descending current at each end. Accordingly, lateral currents, varying in velocity with the strength of the flame, applied under the boiler, will flow inwards over the upper ends of the columns, *f* and *g*.

Several experiments have been made under varying barometric pressure and different atmospheric temperature, but the results as regards the comparative conductivity of mercury and copper have proved to be very nearly alike in all. The accompanying tables record the result of the last trial, conducted as carefully as practicable. The headings of the several columns explain so clearly the object of the tables that it will only be necessary to state that the energy inserted in the fourth column is the energy developed from the beginning of the experiment.

Referring to Table I., it will be seen that at the termination of 4 min. from the commencement of the experiment, the temperature of the water in the cistern, *c*, had increased 29.06 deg., the differential temperature being then 212 deg. — 102.56 deg. = 109.44 deg. During the same period a dynamic energy represented by 2.525 thermal units had been transmitted past the line, *k l*, communicated to (1) the water in the cistern; (2) the part of the copper column immersed; (3) the metal composing the cistern; (4) the immersed part of the thermometer. But, while the entire energy transmitted past the line, *k l*, during the 4 min. thus amounted to only 2.525 units, the rate of transmission was actually 0.850 unit per min. at the termination of the fourth minute. This apparent discrepancy was caused by the heat absorbed by that part of the column which extends above the line, *k l*, the temperature at the commencement of the experiment being the same as that of the surrounding air, 73.50 deg. Referring to Table II., it will be seen that the energy transmitted through the mercurial column, past the line, *m n*, during 4 min., was only 0.087 unit against 2.525 units for the copper column, although the differential temperature of the water in the cistern, *d*, was 137.50 deg.—109.44 deg.=28.06 deg. higher than in the cistern, *c*. Accordingly, the conductivity of the copper composing the column, *f*, has proved to be 2.525÷0.087= 29.06 times greater than the conductivity of the mercury of the column, *g*, notwithstanding the higher differential temperature to which the latter was exposed. It will be observed that the glass, 0.02 in. thick, composing the cylindrical vessel which contains the mercury, will conduct some heat downward, tending to increase the temperature in the cistern, *d*. This tendency, however, will be balanced by the loss of heat occasioned by the radiation of the glass cylinder, since the application of the polished silver socket and the non-conducting covering cannot wholly prevent the refrigerating action of the surrounding air. It is important to observe, regarding the loss of heat from the latter cause, that the cisterns, previous to trial, are charged with water of the same temperature as the atmosphere. Now, considering that the increment of tempera-

ture in the cistern, *d*, does not average more than 0.40 deg. above that of the atmosphere during the trial, it will be evident that the amount of error caused by radiation will be quite inappreciable. We are therefore warranted in concluding that the conductivity of mercury, determined by the increment of temperature in cistern, *d*, and by the dynamic energy transmitted past the line, *m n*, cannot be far from correct. It will be asked why columns of such small diameter have been employed. The principal object has been that of presenting a sectional area in the mercurial column, *g*, corresponding as nearly as possible to the size of the bulb of an ordinary thermometer. Regarding the dimensions, it will be readily admitted that the conductivity of mercury might have

TABLE I.—*Copper Column.*

Time.	Temperature of water in Cistern.	Increment of Temperature in Cistern.	Energy Transmitted past *k l*.	Differential Temperature between Boiler and Cistern.	Energy Transmitted past *k l* per half minute.	Energy Transmitted per sq. ft. per half minute.
Min.	Fah. °	Fah. °	Therm. units.	Fah. °	Therm. units.	Therm. units.
	73.50	.....	....	138.50	....	.....
0.5.....	75.15	1.65	0.143	136.85	0.143	104.873
1.0.....	77.25	3.75	0.326	134.75	0.183	134.208
1.5..... ...	80.14	6 64	0.577	131.80	0.251	184.078
2 0.....	83.84	10.34	0.898	128.10	0.321	235.415
2.5.....	88.14	14.64	1.272	123.80	0.374	274.284
3.0.....	92.81	19.31	1.678	119.00	0.406	297.752
3.5..... ..	97.67	24.17	2.100	114.25	0 422	309.486
4.0.....	102.56	29.06	2 525	109.44	0.425	311.686

TABLE II.—*Mercurial Column.*

Time.	Temperature of water in Cistern.	Increment of Temperature in Cistern.	Energy Transmitted past *m n*.	Differential Temperature between Boiler and Cistern.	Energy Transmitted past *m n* per half minute.	Energy Transmitted per sq. ft. per half minute.
Min.	Fah. °	Fah. °	Therm. units.	Fah. °	Therm. units.	Therm. units.
	73.50	....	....	138.50	....	.....
0.5.....	73.52	0.02	0.002	138.48	0 002	1.466
1.0.....	73.56	0.06	0.005	138.44	0.003	2.200
1.5.....	73.64	0.14	0 012	138 36	0.007	5.133
2.0.....	73.75	0 25	0.022	138.25	0.010	7.334
2.5.....	73.90	0.40	0.035	138.10	0.013	9.534
3.0	74 08	0.58	0.051	137.92	0.016	11.734
3.5.....	74.28	0.78	0.068	137.72	0.017	12.467
4.0.....	74.50	1.00	0.087	137.50	0.019	13.934

been ascertained with greater exactness, if columns of very large sectional area had been employed; but the trial has conclusively established the fact that mercury transmits heat from particle to particle too slowly to effect a sufficiently rapid indication of mercurial thermometers provided with *spherical* bulbs; and that, when the heat is applied from above, the indication of such thermometers is wholly unreliable.

A subject of profound interest presents itself in connection with the rate of transmission of energy exhibited in the sixth column of Table I. It will be seen that although the copper column, *f*, is only 0.5 in. in diameter =0.19635 sq. in. section, the rate of transmission at the termination of the fourth minute is 0.850 unit per minute. Reducing this amount to the usual standard of one square foot, it will be found that the energy developed is $144 \div 0.19635 \times 0.850 = 623$ thermal units per minute for a sectional area of one square foot. It will be observed that this extraordinary amount of energy (theoretically capable of exerting $623 \div 42.7 = 14.5$ horse-power) is called forth by the moderate differential temperature of 212 deg. – 102.56 deg.=109.44 deg. Fahr.

Now, let us compare the energy of 623 thermal units per minute to that produced by the radiation of a metallic surface coated with lamp-black, and maintained at a temperature of 212 deg., within an enclosure of 102 deg. Actual trial shows that under these conditions, the radiant energy of a blackened plate composed of copper, containing 144 sq. in., scarcely reaches 6 thermal units per minute. Our experiment has therefore established the fact, incidentally, that under the stated conditions, a plate of wrought copper 2 in. in thickness is capable of transmitting by conduction from one side to the other, in a given time, an amount of mechanical energy more than one hundred times greater than the mechanical energy developed by the radiation of the same plate during an equal interval of time.

MECHANISM.*

By the Rev. ARTHUR RIGG, M. A.

From the "Journal of the Society of Arts."

In the spring of the year 1869, a course of Cantor lectures was delivered in this room by John Anderson, Esq., of Woolwich. The subject of that course was "Applied Mechanics." Mr. Anderson closed those lectures with the following sentence:—"It will be found that so long as any of Nature's secret laws remain unexplored, well-directed irrepressible thought will alight on new discoveries one after another; and to the endless variations of mechanical combinations there is practically no limit." To some of the elementary forms of "these endless variations of mechanical combinations" our attention in the present course of Cantor lectures is to be directed. It may appear disheartening to enter upon an inquiry which at the outset is said to consist of "endless variations;" but by classification and division, not only all the inhabitants of the world, but all of which the world itself is made, and even the very universe, has been brought under careful and minute examination. The words —animal, vegetable, and mineral—comprehend the world and its inhabitants. Division and sub-division have so placed these that those with similar distinctive features are soon classified side by side.

A digression upon these words for a few minutes, even thus early, will not be out of place. To Aristotle, who was born about 384 years before the Christian era (he died 322 B. C.), we owe much in respect of a development of the system of classification and division. When Aristotle was classifying natural history, and seeking for some distinctive feature by which to distinguish men from every other animal placed in the same class, he selected for him a name appropriate at this day—he called man "a tool-making animal;" for man was the only animal in the creation that made tools for his own special purposes. Had Aristotle lived now, how much more appropriately would this characteristic have applied, and yet our surroundings might have deprived us of the man; for Aristotle was appointed tutor to a youth then 14 years of age—that youth is afterwards known in history as Alexander the Great; but Lord Bacon, in his "Advancement of Learning," writing of Alexander the Great, says, "that he does not choose to consider him Alexander the Great, but prefers to call him 'Aristotle's pupil.'" In these days, and in this country, more indebted as it is than any other in the old hemisphere to the scientific development of the tool-producing faculty, and to many other science faculties, we may look in vain for such encouragement. Alexander did not forget his science tutor, for history records that he allowed Aristotle 800 talents per annum (a large sum, however the talent may be estimated) with which to prosecute his studies in natural history. May it not be that in England in the present generation there are no Aristotles because there are no Alexanders?

By a like law of broad classification we may say of our present subject, there are two marked groups, under one or other of which may be arranged all our mechanistic contrivances. These groupings are comprehended in the words structures and machines. The considerations which present themselves vary considerably, according as one or other of these divisions is under notice, and unfortunately for the science and practice of mechanics in the full acceptation of the term

* A Lecture of the Cantor Course.

mechanics, modern usage has disjoined what should always have been united. The class of men whose business requires that they should attend to the branch called structures disregard the branch called machines. The compliment is repaid. The mind of the man who thinks of structures is ever dwelling upon contrivances for securing stability and perpetual rest, whereas the thoughts of the mechanical engineer dwell upon contrivances for securing motion, and he sometimes dreams of making motion, and not rest, perpetual. Although each of these men look to mechanical aids for accomplishing his purpose, they look at them from two very different stand-points, and in very different colored lights. The man who deals with structures is always thinking of struts, tensions, pressures and frictions, and he adopts those means which seem most likely to secure what he calls stability and immobility. The other man considers that to put the machine in a state of rest, to so proportion the powers as that each elementary part of that machine shall be in equilibrium, is to put a machine in a state of absolute idleness. Now, idle machines, like idle people, do us no good; they destroy themselves, they rust, they in fact decay, and, to borrow the phrase from the workshop, we may say of idle machines that they really "eat their heads off." The true state of a machine, as those who are concerned with them know well, is a state of motion. So completely is this idea of motion impressed upon mechanists, that rest as accomplished by struts and stays and rods, forms no part of the mental employment of the mechanician. A mechanician has no faith in the machine requiring rest. If a mechanician wants a piece of machinery to pause in its work, in order that another part of that machine may go through some operation or other, he accomplishes it by establishing such a relation between and amongst the motions of the respective parts as shall produce the result he requires. As two waves of light or of sound in opposite phases produce, by coalescing, darkness or silence, so two motions can be so mechanically combined as to produce absolute rest. The owner of a machine considers a machine worthy of room on the floor of his factory only so long as it can move and is moving; and, indeed, nowadays, that is hardly sufficient for manufacturers and owners of machinery. Machines are expected to be not only diligent when they are at work, but to go back, when they have done their work, with a speed which no employer has ever yet considered too great. There is no law upon a laborer to return an empty spade to the ground at twice or three times the speed with which he lifts a full one. A machine, however, is expected to do this. It is expected when it has done one stroke of work, literally without turning round, to run backwards at twice or thrice the velocity at which it does its work in order to start and do another stroke. Nor is it in readiness to return to its work at an increased speed that any great triumph of mechanistic skill is noticed. There is hardly a plan or device for the saving of bodily labor, nay, there is hardly a scheme for saving mental thought, that mechanism is not both expected and requested to undertake. Mechanism burrows in the earth, it builds our houses, it conveys us by land and by water, it clothes us, it supplies us with teeth, it will even do a large portion of the work of digestion if we wish, it counts for us, it determines the weight of our gold and silver coins, accepting or rejecting those coins, as, in its mechanical judgment, it deems best; and, to crown all, it thinks for us; it calculates, it sets up its own type, it prints its own calculations, and if by any accident it makes a mistake, it rings a bell and tells us it has done so.

Thus not only English society, but all society depends upon mechanism, and it is, therefore, singular that educational books, and even treatises upon mechanics, lay the foundation of all the information and instruction that they give, not in states of motion, but in states of rest. To put levers, pulleys, inclined planes, wedges, and screws in states of perfect equilibrium, to demonstrate by tedious and complicated reasoning what is called the parallelogram of forces, to be poring over problems for establishing equalities by both geometric and analytical formulæ—these constitute a large portion of the so-called scientific mechanical knowledge contained in our treatises upon machinery for students—at least for those who are beginning to study. If a few advance beyond elementary knowledge, they are generally confronted by still more complicated and uninviting discussions upon the laws which have much to do with motions in the universe, but little or nothing to do with motions on the earth or in our machines.

In 1788, when Lagrange published a great and fine example of analysis, he wrote

in the preface of the book (it was upon machinery):—"The reader will find no figures in this work; the methods which I deliver do not require either instruments or geometrical or mechanical reasoning, but only algebraical operations." Lagrange herein made mechanics subservient to analysis. Analysis ought to have been made subservient to mechanics. Our books of mechanical science deal with questions chiefly of rest or of celestial motion only; hence the man who wants a machine for a given purpose, who wants to combine certain motions, turns in disappointment from volumes that he considers are delusions and snares. So far as power, and so far as strength of materials are concerned, he is satisfied that these are ample for all his requirements. Until he can obtain such a combination as shall secure a special end, questions of construction and equilibrium are not felt by him as matters really of even momentary consideration. He knows that if the motions he needs are won, he will have no difficulty whatever in producing rest. To modify, control, and regulate the motions of connected materials, constitutes the chief object of study with those who hope by machinery to improve upon manual labor. This study is clearly independent of the building of the machine; it is clearly independent of all those parts of the machine that are comprehended under the word "structure." It is also equally independent of the source whence the machine derives its power; and, further, it is quite independent of the work to be done by that power, after it has passed through the machine. What it does involve, however, are any mechanistic contrivances by which motions may be changed, or constrained, or diverted, and that, appearing in one form, existing for a specific purpose, they may be transformed into another exactly adapted to the purpose required. Thus it will be for a prearranged object, and to follow a predetermined law. This is that which is comprehended under the word mechanism, and it is in consequence of the development of this aptitude in the few minds given to the special study—and they have been but few—that England owes all her present manufacturing industries.

Having thus explained what is comprehended under the word mechanism, it may be well to regard what it is that is excluded. All our experience tells us that motion is a consequence of force. So sure are we of this, that we say that whenever force acts motion ensues. If, however, it is wished to arrest an ensuing motion, it is usually done by the introduction of an opposing force. Thus, even in this aspect, rest, observe, is the result of a combination of motions.

The branch of mechanical studies which thus considers force as compelling rest, or preventing a change of motion, is called statics; and states of rest produced by opposing forces, except when the mechanism is called upon in the interval to perform some special operation, do not concern us, and further allusions to questions of statics may be put aside.

But force may produce change, either in the amount or direction of motion, and the branch of mechanical studies which comprehends this is called dynamics. The term dynamics is a marvellously comprehensive one. To say of an operation that it is a dynamical one, gives just about as much information of the operation as to say of a substance that it belongs either to the animal or vegetable kingdom. Division and subdivision must enter, in order to an accurate and instructive investigation of questions of dynamical character. Two of these divisions are so intimately related in the branch of dynamics to be treated of in this course of lectures, that a distinction must be drawn between names much alike. M. Ampere, in the year 1834 (for that is about the time when this subject first began to attain special consideration), wrote:—"Long before I employed myself upon the present work, I had remarked that it is usual to omit, in the beginning of all books treating of sciences which regard motion and force, certain considerations, which, duly developed, must constitute a special science." He then proceeds to describe the science, and calls it kinematics, from a Greek word, *κινημα*, which signifies motion. Further, he makes a proposal which was taken up by others, and the progress of the idea is interesting. He (M. Ampere) defined a machine, not as it had hitherto been considered—an instrument "by means of which we may change the intensity and direction of a given force," but as an instrument "by means of which we may change the direction and velocity of a given motion," hereby excluding force from all considerations of mechanism. Mr. Willis, to whom I shall have occasion to refer again, proposes another definition, namely, to consider a machine as an instrument "by

which to produce, not motion simply, but relations of motion between parts," thus setting aside M. Ampere's definition, that a machine is an instrument to change the direction and velocity of a given motion. Dr. Whewell, in his "Philosophy of the Inductive Sciences," in the first volume, p. 144, has a very short chapter indeed on "Motion," and he was well competent to write a long one. He wrote in that chapter, in 1840: "Motion should be considered quite independent of its cause—force. The science might be termed 'pure mechanism,' in contradistinction to 'mechanics proper,' or 'machinery,' in which force is taken into consideration. Such a science is the science of mechanism independent of force, and I consider it to be the solution of a problem which may be expressed in these words: 'To communicate any given motion from a first mover to a given body.' The necessity of this separation (says Dr. Whewell) has been seen by those who have taken a philosophical view of the sciences." Dr. Whewell, it will be observed, excluded force, and in this respect he follows M. Ampere's views, expressed just six years previously.

Thus has arisen the distinction between two very similar terms, kinetics and kinematics. Each term involves considerations of motion, but in two very different aspects. In kinetics it is not mere motion which is considered, but the relations that motions bear to forces. Hence questions in which the expenditure and nature of force, and the motions produced, are considered, belong to kinetics. Kinetics comprehend the laws of energies and the modes by which men may best avail themselves of these laws. We are too prone as a people to generalize laws, and what we find to be true under one set of energies, we assume to hold good under another set. Such is not the case. The energies of gravity, electricity, vitality, affinity, light and heat, require different treatments, in order that each may be most advantageously utilized.

An example or two may make clear the distinctions now insisted on.

The velocity and penetrative or destructive effects of a cannon ball, in relation to the character and explosive consequences of the energies of gun-cotton, gunpowder, nitro-glycerine, dynamite, or whatever other elements are used, would be a question in kinetics.

Again, that singular calculation, that if a man were engaged in producing a certain motion, as, for example, drawing water from a well, by the expenditure of his muscular energies through the period of his manhood, he would raise by the mechanism of his bodily frame no more water than could be raised by one load of the best Wallsend coal; hence completing the parallelism, and reducing it to the form of money value—and it is wonderful how much more we appreciate these things when they are put in a money value—the life energy of a man acting through the mechanism of his muscular system does not exceed the energy of a load of coals employed through the mechanism of a scientifically-made engine. In other words, given the two mechanisms, the life of a man is not worth more than about 60s. Had man been created for no higher destination than this, we may depend upon it he would have been put together as a piece of mechanism very different from that on which he is now constituted.

In kinematics these elements of force occupy no attention whatever. Neither the force that produces the motion, nor the forces impeding the motion, nor the forces that these two motions call into action, none of these belong to the division of the subject with which these Cantor lectures have to deal. Kinematics, therefore, is a science of mere motion; even elements of strength are not considered in it. The galloping tortoise which we see advertised in the windows in the streets of London, and that tricky little mouse that you see creeping up the hands of men in Oxford street or Lombard street, claim from mechanicians quite as much attention, and involve questions of mechanism perhaps quite as curious as Babbage's calculating machine, or those singular things, the orreries of the last century. It is, therefore, the division of the subject called kinematics with which the present course of Cantor lectures is chiefly concerned.

M. Ampere appears to have been the first to direct public attention to the importance of kinematics as a special study. Plato speaks of astronomy as "the doctrine of the motions of solids;" and to come to recent times—very recent indeed—there is a still valuable work by Emerson, which we have here, and which contains some very good illustrations. Here is one of the mechanism of a rat-trap, and very well it is done. The reason why the book is produc-

ed is this. It was probably first published about 1750; this copy, which is the second edition, corrected and very much enlarged, with 43 copper-plates, was published in 1758. The title-page is well worthy of our consideration in connection with the present course of lectures. It is—

THE PRINCIPLES OF MECHANICS,

Explaining and Demonstrating

THE GENERAL LAWS OF MOTION.

The Laws of Gravity.	Centres of Gravity.
Motion of Descending Bodies.	Strength and Stress of Timber.
Projectiles	Hydrostatics.
Mechanic Powers.	Construction of Machines.
Pendulums	

A work very necessary to be known by all Gentlemen and others that desire to have an insight into the

WORKS OF NATURE AND ART.

And extremely useful to all sorts of Artificers, particularly to Architects, Engineers, Shipwrights, Millwrights, Watchmakers, &c., or any that work in a Mechanical Way. The Second Edition, with 43 Copper Plates. 1758.

The order of Emerson's subject is remarkable. They begin with motion, lead on to equilibrium, and end with structures. In our days the habit seems to be to begin with structures, descending through equilibrium, and very seldom proceeding so far as motion is understood in mechanism. In the preface he lays great stress upon motion, and not, as in modern books, equilibrium; on that he lays no stress. He writes:—"What else is there in the visible world but matter and motion? Mechanism is a science of such importance, as without it we could hardly eat our bread, or lie dry in our beds, and by it we come to understand the motions of the parts of an animal body—the motions of the celestial bodies. Without mechanics a general cannot go to war, and the meanest artificer must work mechanically, or not work at all, so that all persons are indebted to this art, from the king down to the cobbler."

Although pure mechanism in kinematics has thus been recognized as an important study in and by itself, yet no work appeared in the English language, as far as I know, until the year 1841, one year after Dr. Whewell's book, which was six years after M. Ampere had drawn attention to this subject. Then Professor Willis, the Jacksonian Professor of Natural and Experimental Philosophy in the University of Cambridge, published a volume on "The Principles of Mechanism, designed for the use of students in the University, and for engineering students generally." To this work all who have alluded to mechanism acknowledge great obligations.* In it the subject is treated as a mathematical one, and although in the present course of lectures the purely mathematical aspect of the problem must be ignored, that is no reason whatever why the young mechanicians should not study the subject with the only key that can unlock for them its treasures.

Whilst allowing the "open sesame" character of this mathematical key in the question of mechanism, it is well to avow that purely mathematical minds have claimed for their favorite science far too much of the power of a magician's wand over terrestrial mechanics and mechanism. Mathematicians boast that they hold the key of the gate; it is a reflection upon their good taste that they seldom walk in the pleasant pastures of which they have the key. If mathematicians would but become as familiar with the technicalities and wants of machinists and mechanists as they are with the omnipotence of x and y, they would often receive the right-hand of brotherhood, where now men are provoked to say, "Stand back, we do not want you." There will be no solid progress in the refinements and precision of mechanism, either constructive or kinematical, until there is less dissociation between mathematics, physics, kinetics, and practice. The youth of England are led in the dynamical relations of x and y to calculate the path of the earth in its orbit, and they can do it to a second in a year. The same x and y enable them to tell the periods of the revolution and rotation of the earth; to find the velocity of light, and to measure the length of its waves to the millionth of an inch; to calculate the exact curve of the spectroscopic diagrams in the solar corona, and this with an accuracy that even decimals fail to represent to the mind. Such is considered a triumph of mathematical dynamics. But ask a mathemathician to determine the quantity of irregularity produced by an unbalanced fly-wheel; to say how a small weight on a large fly-wheel may produce back-lash through a mill, and destroy the teeth of some of the largest wheels in that mill, or to state in what motions or how to utilize the heat that passes away, or to what influences a ship is subject by the rotation

* The second edition of this work has been recently published by Messrs. Longman, and to them and Professor Willis the Society of Arts is indebted for the loan of certain wood-cuts to be used in the printing of future lectures.

of heavy machinery within, or to calculate in any given case what is called negative slip; and how is that slip in a screw propeller to be avoided? Ask the mathematicians to take a given problem, with given numbers, under any of these heads, and they will turn from it and think it beneath their notice—probably it is beyond their skill.

Mechanism, then, is the alphabet; machinery is the written expression, and that machinery is a combination of parts. These elementary parts are furnished by the mechanician. Hence the study of mechanism should precede the study of machinery; but it has failed and still fails to do so.

Apart entirely from the mathematical and scientific reasons why mechanism does not hold its own as a branch of well-defined and intellectual study, there are one or two obvious social ones. Mechanism is not directly allied to utilitarianism; it bears a relation to utilitarianism of a character similar to that which art bears to it. The necessities of life must first be met, and then may be entertained improved means for meeting them. Houses, boats, bridges, clothing, and food must first be procured, and then, and not until then, need be considered the the best way for accomplishing these, or for rendering them more attractive when they are procured. Hence art and mechanism first succeed, and then precede, utility. Again, our very bodies, and the contrivances which nature has so profusely scattered around, have given man what may be called an intuitive knowledge of mechanistic combinations. Men avail themselves of these as they do of books in a library, and rarely give a thought to anything but the branch that they are themselves at the time wanting.

Mechanicians are only a numerous class of those who do this. To the extensive storehouse of nature's contrivances, perhaps every branch of art and science resorts more than it is willing to allow. When the Government, about 100 years ago, referred the question of a lighthouse to Smeaton for the Eddystone rock, Smeaton, who was experienced both as a kinetical and constructive mechanician (he was the first to introduce the use of cast-iron teeth in large wheels), did not contrive a lighthouse, or even consider he was called upon to design one. What he did was to look about through nature's storehouse, and to consider where and how resistances were met similar to the resistances he was called upon to meet. Hence, when he published a report, in folio, of the designing and executing of the present Eddystone lighthouse (three or four previous ones having been either burnt down or washed away), he printed, side by side with a drawing of the structure he proposed, the trunk and branches of an oak tree, which he took as his model. On the wall is a diagram taken from Smeaton's own account of the Eddystone lighthouse, and showing the peculiar mode in which he dovetailed the stones one into the other. The question of the Eddystone lighthouse is quite foreign to our present purpose, but the diagram there shows the mode in which the oak branch enters into the stem of the tree; and in the text Smeaton points out how beautifully the obtuse angle of the branch is fitted in with more material than the acute angle, and how it strengthens the acute angle; he also shows how the stem of the tree is fixed into the ground, and to this natural contrivance he owed his ideas, for from them he writes: "I could make a figure not ungraceful; and at the same time carrying the idea of great firmness and solidity" (p. 42). That is sensible constructive mechanism. There may be many in this room who remember the year 1851, when the country was very much perplexed to know what to do with the Exhibition it had summoned, and did not know how to put it under cover. Architects, engineers, and others were completely baffled. They felt that if they raised a building, either of brick or stone, damp in the walls would spoil the treasures of art to be deposited there. No available suggestion originated with them. In the crisis a gardener came forward, and to him is due the credit of having suggested the design for the building. Sir Joseph Paxton, who owns he was no engineer, writes of the Exhibition of 1851: "Nature was the engineer in this case," and he requests those who choose to do so to compare the leaf of the water lily (the "Victoria Regia") with the building erected in Hyde Park, for he says, "from this I obtained all my ideas," of what should be comprehended in the first iron and glass building that was ever seen. Let us look—the inquiry shall be as brief as possible—at a few more of similar illustrations. A spider's web across a garden path suggested the Menai bridge to Telford before 1818. The structure of bones sug-

gested the tubular one which carries the railway across the Menai Straits. The little worm which perforates the wood of ships suggested the Thames Tunnel to Brunel; the telescope, the microscope, and the camera obscura are all clearly set forth in the eye; it was a lobster shell which gave the idea of curving wrought-iron tubes to Watt; wasps make paper, and there are other wasps that make paste-board. Spiders form nets; hail and shot are formed exactly alike. Bird's feathers suggested the slates to our houses, and bird's nests are lessons to this day in basket weaving. England, as an island, is warmed as this room is warmed. In the torrid zone there is a boiler and furnace, and the Gulf Stream is the enlarged pipe of a huge heating apparatus. In the hand we have a vice, and looking at that vice which we all possess from a mechanical point of view, it is evidently one more perfect than the most ingenious vice the accumulated skill of engineers could possibly produce. There are eight or nine different vices in one, that is to say, it is a vice of varying size and form; it needs no clams; there is no chance of damaging the work put in it by the serrated edge, as is the case in an ordinary vice, for, as you know, clams of wood, lead, cloth, and other materials, are used to save the work. Look at it from any point of view, it is unapproachable. If you want to hold a circular piece of metal, how much more beautifully do you do it than can be done by any contrivance of engineers. You hold it between two fingers and a thumb. Although this is a question of statics, it is worthy of a few moments' consideration. You observe, many people put things upon four legs; theodolites*, instruments, tables, etc., are generally put upon four legs, but Nature tells us we should put them upon three. When this pencil is held on three sides by two fingers and one thumb, you cannot press it in any direction without its meeting with resistance, but once put it between four fingers and there are four places in which it may escape. Another peculiarity of this vice (viz., the hand) is, that you may hold a chisel in it so as to be quite steady, and yet it will slide along, and there is no vice known to me which will do this. This vice, then, is not only a very curious one, but, in respects which would draw us very far aside, it is one possessed by no animal except man. Look, again, at the wrist joint. We have vices with balls and sockets, and universal joints, but none equal to this universal joint at the wrist. There is a fortune for anybody who can make a vice to equal it, so simple and so universal. Then, again, the stomach is a perfect laboratory. The lungs are a bellows; the skull is an arched vault, beautifully put together; and the teeth!—what a complication we have of knives, saws, wedges, and millstones; and in the jaws there is an arrangement which has often been tried, but which has never yet been successfully attained, called a draw-cutting action, the nearest attempt to which is in bread, hay, and paper-cutting machinery. Not only is the eye a telescope and a microscope, but there is in its apparatus, viz., in the "iris," a specimen of what engineers have been attempting for a long time—an expanding pulley. No expanding pulley has yet been successful. To adapt such suggestions as these supply, and to combine them with the structural schemes which ingenuity or necessity furnished, seemed to satisfy all the wants of men until the steam-engine enlarged its usefulness by giving a rotary motion in addition to a reciprocating rectilineal one. Watt did this in 1770, and from that time we began to date our mechanical progress. Then it was that men who saw a high scientific and intellectual study in mechanics were gradually turned from such considerations as the mathematical demonstration of the parallelogram of forces, or the abstract beauties of algebraic analysis, to the more important considerations which these engines producing rotary motion led them to entertain.

When we note how slowly, even in these days, the direction of men's thoughts changes, we must not be surprised that comparatively few minds have left the beaten track, and entered on studies of pure mechanism. It is, both in its abstract and practical character, a very fascinating study, and those who promote it render the art of the mechanic less empirical and far more scientific than it is at present. As an architect should study engineering, so a mechanic should study mechanism. A mechanic, as the term is applied, means one who makes machinery. This view is just as narrow as that which would restrict the term engineer to one who drives an engine. If there is one occupation more than another which should win

* The adjusting-screws of theodolites are, as a rule, four in number—the three-legged stand is the support of a four-legged instrument.

respect from the required combination of mental knowledge and handicraft skill, it is that of the mechanic; and of mechanics, none need these qualifications more than the smith—

> "A mighty man is he,
> With large and sinewy hands,
> And the muscles of his brawny arms
> Are strong as iron bands."

For that man can take an uncouth, shapeless mass of cold iron and so correctly judge of the volume of that uncouth mass as to select the required quantity, and no more, for a form to which it bears no resemblance, and to which form he shapes it, although he is never able to touch it with his fingers. Before you is one of the recent triumphs of skill in wrought iron; and if there is any one present who has taste for work of that kind, it is well worth study. It has been lent by Messrs. Peard, Son, and Peard, and is a pure piece of wrought iron. It is most artistic and graceful in form, and is put together without brazing in any part. How far it has been screwed together, or how far it has been simply welded, there are, no doubt, those in the room fully competent to judge. No one, however, can leave it without admiration, and recognizing the truth of the statement, that of mechanics there are none who more deserve the thanks of the community than the class called smiths.

The relation which the machinist bears to the mechanist is easily defined. Setting aside the question of structure, the mechanist deals with designs; the machinist takes those designs and adapts them to his purposes. For the fitness of the designs for an end, they apply, when need be, to the mathematician. The mechanic takes the deductions of the machinist and the mathematician, and produces a machine as exactly adapted to the purpose required as the knowledge and experience of the time enables him to do. The distinction thus drawn between the machinist and the mechanician leads to modes of expression by these respective classes which, unfortunately, do not increase the respect of each for the other. For example, the mechanician aims only at a contrivance; the machinist or mechanic aims only at a commercial or manufacturing utility. A mechanician is contented with the most rude skeleton design; he does not care for either journals or plummer blocks being neatly and carefully curved out—anti-friction curves do not trouble him. On the blackboard are two skeleton drawings—here is a very rude one of two wheels and a crank—these answer the purpose of the mechanician. A mechanic would not be worthy of the name of mechanic if he executed such a piece of work; as a mechanical drawing it is perfectly ridiculous. You see by the side of it some specimens of mechanical drawing, one a diagrammatical one, and another a most beautifully-finished drawing of a locomotive, which, perhaps, appears to many to be an engraving. It, however, is done entirely by hand. There are also working drawings, such as are taken into the workshop, from which the actual machines are made. It would certainly be a great improvement on scientific books if there were some advance in the illustrations they contain, which at present are often even less worthy of commendation than the rude mechanistic skeleton one alluded to.

It is quite possible, and it would be even prudent, to make mechanism a study altogether apart from mechanics; it would not, however, be prudent on the present occasion to do so. Whilst, therefore, associating mechanism with mechanics—to which it is not allied, and separating mechanism from mathematics, to which it is necessarily allied—in this course of Cantor Lectures we approach the subject in a species of bondage, and must therefore ask that favorable consideration generally extended towards a comparatively strange friend, by making use of our old friend, mechanics, for a favorable introduction and an occasional help.

With mechanics we are all familiar. We can neither eat, drink, nor sleep, we can neither sit, walk, nor talk, except by the exercise of those mechanical arrangements with which nature has endowed us. When, however, in the course of nature the vital energy ceases by which man is enabled to put in action the machinery of his frame, then, however beautiful and perfect the machinery may be, the object for which it was constructed cannot be performed. At this stage (the power of the machinery having gone—the kinetical element having been removed) the machinist takes up the parts, and may be said to analyze the contrivances by which the vital energies exercise their various powers. But the mechanic cannot operate without a motive power. The mechanician cares for none. He deals

with contrivances in relation to motion. His peculiar province is to devise plans by which the motion he has may be changed into the motion he wants, and the requirements he wants are singularly varied, and they fully warrant Mr. Anderson's expression of "endless," for to them there is "practically no limitation." Farmers do not make more varied demands upon the weather than machinists do upon mechanists in relation to motion. There is no end to the variety of demands made by the public upon the mechanician. One man comes and says he has a motion which he wants accelerated. Another says he has a motion which he wants retarded. A third comes and says his motion is not quite continuous, he would like it to be so; another says he wants the motion to be intermittent. One man says he wants a circular motion when he has got a rectilineal; another says he wants a rectilineal when he has got a circular; another wants it variable; another says he wants it uniform; one says it must be alternate, going backwards and forwards; another says he wants his motion brought to a state of rest. Another says, here is velocity, convert it into power; and another, here is power, convert it into velocity. None of these, and the list might be wonderfully extended, are out of the province of the mechanician. For example, a knife is to be sharpened. There are various modes of doing it. The shelves of the Patent Office have many for sharpening knives, but we will take the representative one, in which the stone revolves. We have an apparatus here for which we are indebted to Messrs. Holtzapffel. The problem before the mechanist is to convert the perpendicular motion of the foot up and down about eighty times in a minute into a continuous motion of the stone of about 500 ft. circumferential per minute. The plan adopted here is to have a treadle for the foot, by which the up-and-down motion is transferred to a wheel, from which there is a band to a small pulley connected with the stone, and by this contrivance we have got the up-and-down motion of the foot converted into the continuous rotary motion of 500 ft. per minute. That mechanism is perfect for all purposes, not simply for the sharpening of a knife, or razor, or lancet, but, as a mechanical contrivance, it will do for a hatchet, scythe, or any other edged tool. The machine has left the mechanician's hands as a contrivance, but the mechanic takes it up, and adapts the question of its structure to the particular use for which it is required, using such proportion of treadle, crank, and wheel as he pleases. The mechanist has done with it when the contrivance is produced, and it then becomes the property of the mechanic. If, however, the problem had been set before the mechanist in another form, as, for example, if he had a weight falling, and that had to be converted, or if he had got such a matter as the rise and fall of the tide, and that had to be converted, or, if he had got the explosive power of gunpowder, or the intense power at a short distance of electricity, or the elastic power of a steel spring, then clearly these would be new conditions imposed upon the mechanist, and a different piece of mechanism would have had to be designed for each of those cases. You have, therefore, according to the questions put before the mechanist, various machines, but one contrivance serving every purpose. In any case the mechanic takes the designs of the mechanician, and so avails himself of his own knowledge of material, and so adapts the amount of power at his disposal, and of that required to be utilized, as to make the machine.

Now it is clear that to sharpen a razor and a hatchet requires from the mechanic two different machines—from the mechanician they require but one mechanistic contrivance.

Having thus explained and illustrated the position which mechanism holds in relation to other branches of mechanics with which it is allied, we should restrict ourselves to a consideration of the divisions and sub-divisions under which it may be usefully studied. To do so in the present course of lectures would be to make the subject not particularly inviting, and we must sometimes therefore overstep the boundaries, and take a short walk into the not very inviting mathematical and prohibited fields, and perhaps a longer one into the more inviting mechanical fields. In thus, to some extent, trespassing into tempting by-paths from the highway which the literal meaning of the title of these lectures prescribes, the Council of the Society, and the audience, who do not despise mechanistic drawings, must permit action to take place under a precept which, not existing in our Christian code, I must borrow from another:—

"For what saith the Koran in chapter the third, 'Confine not thy neighbor too close to his word.'"

STABILITY OF GIRDERS.

From "The Engineer."

The rigidity of a girder, or the resistance it opposes to any change of form or motion among its several parts, will depend principally upon the due fulfilment of a very few conditions. The proportion of the span to the depth, the ratio of the former dimension to the width of the booms, and the character of the load the girder has to bear, are the chief points to be attended to. It is supposed in this instance that the girder acts independently, and that its own stability is not derived in part from any system of bracing or trussing which unites it to one or more fellow girders. If cross bracing is used, then the question is not of the stability of a single girder, but of the whole composite structure of which each girder is a separate part. As a rule, the separate girders designed for bridge and roof purposes are interbraced and tied together in a more or less effective manner, so that the individual stability of each is, in a great measure, lost; but it must nevertheless be borne in mind that the more defective a girder may be in stability, *per se*, the greater amount of trussing and bracing it will require when several of the same type are joined together in one structure. As all the material consumed in imparting an adventitious stability to girders is so much dead weight, and does not count in the actually calculated resistance to strains, it is evident the less that is necessary the more economical will be the result. We have seen some girders so badly proportioned and designed that a large quantity of bracing was required to force them into shape, and subsequently additional trussing was needed to maintain that shape unaltered. A certain amount of stiffness is indispensable to a girder, although that feature is not by any means a sure indication of either its strength or security. It is quite possible to construct a wrought-iron girder, and stiffen it by the lavish employment of extra material in such a manner that it would hardly afford the slightest premonitory sign of yielding, even when it was on the very point of rupture. While, therefore, stiffened almost to brittleness, its absolute strength would be comparatively small. There is no question but that the form of the girder, the shape of the booms, the character of the web, and the type to which it belongs, are very material points to be considered with reference to our subject. But the points to which allusion has been made, affect the stability of all girders, independently of the particular class to which they may happen to belong. Girders frequently become unstable from the practice—at one time very prevalent, and still adhered to in too many instances—of loading them on only one-half of the flange. However well the principle of uniform stress on the flange might be carried out in the design, it would be rendered completely abortive by such a disposition of the working load.

The proportion between the span and depth of girders depends in some degree upon their nature, and also upon the judgment of the engineer who designs them. Time, and additional experience in the designing and construction of iron bridges and roofs, have lent their influence towards greatly modifying many preconceived ideas on this point. Girders having continuous webs—such as the tubular, box, and plate forms—require in an economical point of view a less depth than those belonging to the open web girder. Thus, the depths usually assigned to girders with continuous webs range between $\frac{1}{12}$th and $\frac{1}{15}$th of the span. In fact, the proportions originally adopted in the early designs of iron bridges have been adhered to in the later examples with tolerable closeness. If the span of a girder be constant, and the depth be gradually diminished, the girder becomes speedily very unsteady. It ceases to possess any rigidity, for since the deflection of a girder with parallel flanges is inversely as the square of the depth, the limit is soon reached when the structure becomes absolutely insecure. A considerably greater depth has been used to advantage in the case of braced girders, which may be regarded as constituting the modern type of bridge and roof building. The ratio varies between $\frac{1}{12}$th and $\frac{1}{4}$th of the span. In America, where some gigantic specimens of timber trussed bridges exist, a proportion of $\frac{1}{4}$th has been adopted in some instances. For iron girders of the open web description a proportion of $\frac{1}{10}$th of the span for the depth will give good results. There is another feature in the design of a girder which bears prominently upon its stability, and

that is the ratio of the width of the flange to the span. The relation it bears also in this respect to the depth should not be overlooked. A very deep and at the same time very narrow girder would be exceedingly likely to cant over, without the dimensions of the span possessing much influence in the matter. To go back to the Britannia Bridge, which to some extent is still unrivalled as an example of iron construction, the proportion of the width of the flange to the span of the girder is as high as 1 to 31. But this is an exceptional instance, as the flanges in reality consist of entire booms composing the whole cross section of the structures. A very good general proportion is about $\frac{1}{40}$th. The plate girders in the land spans on the Middlesex end of the Charing Cross bridge are designed with span, depth, and width of flanges in the ratio of 1, $\frac{1}{2}\frac{1}{0}$th, and $\frac{1}{3}\frac{1}{0}$th. In girders with cellular tops, which are now obsolete, the proportion of $\frac{1}{8}\frac{1}{0}$th of the span has been adopted for the width of flange.

Passing on to the braced form, it will be seen that the flange of some well-known examples exhibit a still greater reduction in their ratio of width to the span. In the Newark Dyke bridge the proportion is as 1 to 160, and in the Crumlin Viaduct only as 1 to 200. The flanges of the girders of this latter structure are only 9 in. in width. It is not to be wondered at that both of these structures evinced a great want of lateral stability, and required to be strongly interbraced and tied together throughout the whole of their longitudinal and transverse sections, in order that they may undergo with safety the heavy rolling load to which they are subjected. So long as the load is of a stationary description, and situated either at the centre or uniformly distributed over the whole length of the girder, there is nothing to affect its lateral stability, and the flanges might be reduced in width to almost any dimension, provided the extremities over the bearings were kept in place. But the advent of a rolling load alters the conditions very materially, and calls for an amount of rigidity and stability which few girders possess by virtue of their independent construction. Cast-iron girders are exceedingly well circumstanced in this respect. The great disproportion which exists between the compressive and tensile strength of this material induces a similar discrepancy in the respective sectional areas of the upper and lower flanges. The latter, in consequence of containing from five to six times as much metal as the former, is generally very broad in comparison, and thus can be firmly secured to the abutments. The lateral stability of this description of bridge is further aided by the small depth given to the girders, and the introduction of a few tie rods passing through their respective webs. Small as the width of the flange of the Crumlin girders may seem in relation to the span, that of some of the bowstring and curved trussed girders adopted for station roofs is less. The roof of the New-street Station, Birmingham, has double-headed tee-shaped rafters for the principals, whose breadth is about the 212th part of the span. Obviously no rafters of these proportions could possibly remain upright without the assistance of bracing, which is furnished by the nature of the structure. The roof itself constitutes a continuous bracing between each pair of rafters, so that it is not a question, as has been before remarked, of the stability of any single girder, but of the whole roof together. Besides, being subjected to no rolling load, a roof can be more thoroughly braced together than a railway bridge, and with far more economy. In the latter case, therefore, the proportion of the width of the flanges of the girders to their span is not of so much importance.

THE TAY BRIDGE.

From "The Mechanics' Magazine."

The new Tay Bridge, now in course of construction, will be the longest bridge in the world—longer even than the Victoria Bridge, Montreal. The Victoria Bridge is 9,194 ft. long, while the Tay Bridge will be 10,321, making a difference in favor of the Tay Bridge of 1,136 ft. Had the Tay Bridge being eighty yards longer, it would have been two miles exactly, and for all intents and purposes it may therefore be called a two-mile bridge, and will have 90 piers and 89 spans.

The details of the vast undertaking are of interest. The work was to be completed

in three years from May, 1871, and the dimensions in detail are as follows:

Between the abutment on the Fife shore and the abutment at Magdalen Point, on the Dundee shore, there are to be 89 spans, three of which—counting from Newport—will be 60 ft. wide; two of 80 ft.; twenty-two of 120 ft.; fourteen of 200 ft.; sixteen—counting from the centre of the bridge to the Dundee side—of 120 ft.; twenty-five of 66 ft.; one of 160 ft.; and six of 27 ft. The greatest height of the bridge will be 88 ft. above high-water mark. The bridge is slightly in the form of an arch. Leaving from the Newport side, the gradient is one in 100 for three spans, and from this point it is only one in 353 until the centre of the bridge is reached, and drops again with a gradient of one in 73, and continues at this until the Dundee shore is reached. The piers are made double, and are in the form of cylinders, made of cast iron, which are again filled in with bricks. The quantity of cast iron required for the cylinders is 2,600 tons, while the superstructure is all malleable iron, 3,600 tons of which is required. There are at present about 90 men employed at the works. The contract for the whole bridge was taken by Mr. De Bergue, for £217,000.

The braced piles that will be used from the north side weigh 650 tons in all. There will be about 36,000 yards of brick and concrete work, and some 87,000 cubic feet of timber. The operations in the construction of the bridge are peculiar. The usual manner of laying piers of the kind used for the Tay Bridge is to erect heavy staging, from which the cylinders of the pier are guided into their places. But in this case there is not depth of soil for pile-driving. The cast-iron cylinders and brickwork are first built on the shore, at the water-edge, then floated into their places by means of pontoons, and lowered into position by hydraulic apparatus. The excavating for the foundation must be done with great care, and is accomplished by the ordinary air-compression system. The solidity and stability of the whole structure must depend on the firmness of the base of the cylinders, and there must be great exactness in the fitting, and strength in the cement used in the brickwork and concrete. A piece of the cement, 1½ in. sq., which had been used on December 19th, and since then kept in water, was submitted to strain, breaking at 1,120 lbs. This cement becomes stronger the longer it is kept in the water, up to a period of five years, when it reaches its maximum strength. The first cylinder was floated into its place on October of last year, and was finished by November 29th. The three rectangular piers are 68 ft. high, measured from high-water mark. Two of the spans, or superstructures, of the rectangular piers are already placed, while more are about ready. Four pier foundations are finished, which are the most tedious part of the work. The new plan adopted in the construction of these piers, which joins the two cylinders into one, gives great compactness and strength in the simplest way. The laying of the first six or eight pier foundations is made more difficult from the depth of water, which at full tide is about 32 ft. and 18 ft. at low tide. The bridge is for a single line.

A Coating of nickel adds so much to the beauty and durability of most objects made of cast iron, wrought iron and other common metals, that the following process, published by Stolba, must prove very valuable if the deposit is at all equal to that produced by ordinary plating. A quantity of concentrated chloride of zinc solution is placed in a clean metallic vessel, and to this is added an equal volume of water. This is heated to boiling, and hydrochloric acid is added drop by drop until the precipitate which has formed on adding water has disappeared. A small quantity of zinc powder is now added, which produces a zinc coating on the metal, as far as the liquid extends. Enough of the nickel salt (chloride of sulphate) is then added to color the liquid distinctly green; the objects to be plated are placed in it, together with some zinc clippings, and the liquid is brought to boiling. The nickel is precipitated in the course of 15 minutes, and the objects will be found to be completely coated. The coating varies in lustre with the character of the metallic surface; where this is polished, the plating is likewise lustrous, and *vice versa*. Salt of cobalt affords a cobalt plating, which is steel grey in color, not so lustrous as the nickel, and more liable to tarnish.

There are 17 pneumatic tube lines in operation in London, varying in length from 980 yards to 29 yards.

PETROLEUM.

(*Continued from p. 228.*)

II.

A REVIEW OF THE MOST IMPORTANT CHANGES FROM THE OLD TO THE PRESENT APPLIANCES USED IN ARTESIAN DRILLING.

Whatever overestimate may at any time have been placed upon the business of oil producing, the remarkable genius and self-reliance of the operator himself in the rapid improvement of the machinery used for the purpose, merits well our interest and attention.

When this advance is fully understood, justice to the operators cannot fail to concede that, as a class, they are men of more than average capacity; the art of Artesian drilling and pumping has with them reached a point which, as an old driller remarked, "seems perfection itself;" the latest and best books on the subject as well as the last Encyclopædia are alike waste paper, while to look back at the celebrated well of "Grenelle," in France (so long a standard in deep borings), we would find the drillers but babes and novices in their calling, and their wonderful tools only a poor assortment of fantastic old iron.

Such improvements, too, as have met with successful adoption, have been devised invariably by the operators themselves as the result of practical experience in supplying a want; the happiest inventions of other occupations have often been the work of men totally disconnected with them, but there is not in use to-day, within the writer's knowledge, a single successful improvement that is the effort of an "outsider" or of the men whom the world regards as its brighter lights in science or mechanical skill.

Their operations, nevertheless, are free from all superstitious or foolish precedents which are so liable to follow a purely practical education on any subject; the quarryman, for instance, "slows" his powder with sawdust, and feels better for the practice, but it is rare indeed to find useless metal or wasted motion in the tried appliances of the oil country.

It would hardly be possible within the limits of this paper to attempt more than a condensed description of that which is prominently novel, still less so to include all of even the most valuable inventions relating at this time to well-boring, and it is with no intention to discriminate that the ones here mentioned are selected. In fact, even a thorough treatise on anything as progressive as this has been, is liable to be soon out of date.

To understand what has been done let us look back to 1869–'70. A small 4-horse portable engine, a set of 300 lbs. drilling tools, light band and bull wheels of about 4 ft. diameter, and a derrick just high and strong enough to hold a farm dinner-bell, completed the necessary outfit at this time; the wells then were 3 in. holes with a maximum depth of 300 ft.

A leather bag filled with flaxseed and tied around the tubing below the line of the surface water, excluded it by the swelling of the flaxseed from the oil-bearing rock; but whenever the tubing was drawn, which was a matter of constant occurrence, the surface water poured at once into the crevices below.

For the consideration of the present method of drilling, let us divide our subject into five parts—the rig, the well, the motive power, the tools, and pumping.

THE RIG.

The rig is composed of the derrick, band and bull wheels, sand-pump reel, sampson-post, walking-beam and engine-house.

The present derrick is built "balloon frame," 12 to 16 ft. square at base and from 50 to 60 ft. in height, resting on hewed oak sills, 12 in. by 18 in., framed and pinned at corners; the four corner posts are of pine plank 2 in. by 10 in., spiked together on an angle, and connected with cross-ties and diagonals of 8 in. by 1½ in.; the top holds the usual cast-iron derrick pulley and a ladder to reach it is constructed upon one side.

The bull wheel now in use is shown in Fig. 1. Four main arms, oak, 8 in. by 2½ in., pass clear through the shaft and are locked and keyed; the false arms between, 2 in. by 6 in., wedge upon each other at the shaft and are firmly held by the three thicknesses of pine boards forming the outer rim.

The total length of oak shaft is from 10½ to 12 ft., diameter 13 in., length between

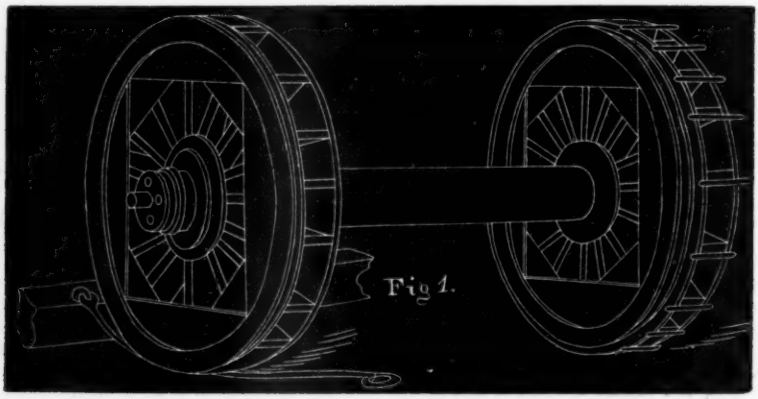


Fig 1.

wheels 6 to 7 ft., diameter of wheels 6½ to 7 ft., bearing pin on ends 2½ in. by 4 in.

The manner of securing the iron bearing pin and plate to the end of the oak shaft is shown by Fig. 2.

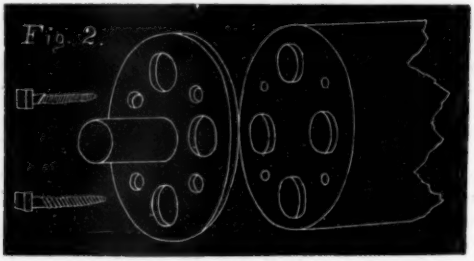


Fig. 2.

The brake is a simple iron strap or rope applied as shown in Fig. 1., and a wooden pawl is used to fall from above against the arms as a permanent stop when desired.

In the band wheel but little change is apparent except that of increased size, the present diameter being about 7 ft. and the rope pulley wheel on the side 5 ft.; the face of the wheel is 9 in. and the whole is built of inch pine lumber, surfaced to a uniform thickness.

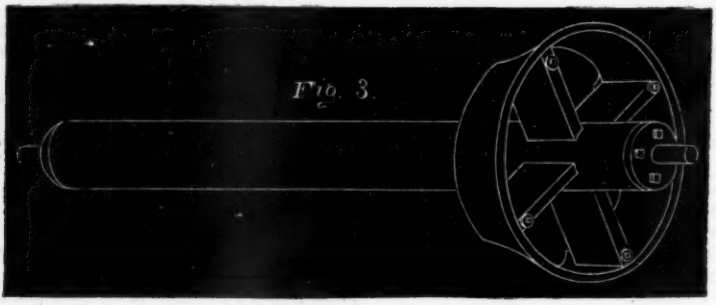
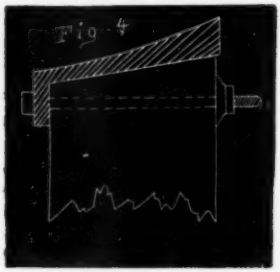


Fig. 3.

The grooves of the rope pulleys on both band and bull wheels are made of hard wood, and to insure a perfect outer circle, the edges are turned off after the wheels are firmly mounted on the shaft, and revolved on temporary bearings.

The sand-pump reel has, until recently, been an apparently awkward and clumsy af-

fair; acting as a friction pulley against the band wheel, with the bevelled face necessitated by the different angle of the shaft, its tendency was to self-destruction even when most carefully and securely fitted up; the style shown in Figs. 3 and 4, is perhaps the best means of obviating these difficulties,



the iron rim, as will be seen by the section shown in Fig. 4, being kept and adjusted by the bolts firmly in place on the arms.

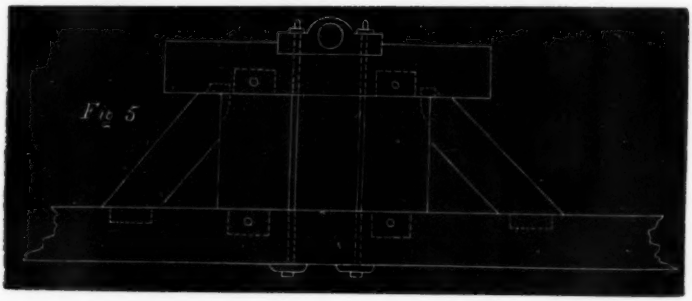
A solid wheel of hard wood with wooden keys is sometimes used, also a piece of casing with bearing pins in the end, and an ordinary cast-iron pulley-wheel keyed upon it.

The shaft shown in Fig. 3 is of oak, about 8 ft. in length, 8 in. in diameter, and with bearing pins of the pattern shown in Fig. 2, the arms of the wheels passing through the shaft.

The sampson-post and walking-beam have gradually increased in size until the one is a post of 20 in. square, and the other from 20 to 24 ft. in length with a section at the centre of 30 by 18 in.

The great weight of the walking-beam, has perhaps somewhat of the effect of a fly-wheel, where a fly-wheel nevertheless is not found to be a practical success.

The utmost care is shown in making the foundation of the sampson-post and band wheel frame perfectly solid and substantial; two long hewed oak sills for the latter, not less than 12 in. by 20 in., pass clear under the derrick sills, the posts, cap and braces of band wheel frame, as shown in Fig. 5, being of pine, 10 in. by 12 in., the caps bolted through to the sill.



THE WELL.

To Col. Drake we are indebted for the invention of the driving-pipe, which, if patented at the time, would have given him the fortune his pluck deserved. As a means of passing through the soft earth overlying the rock, it probably will never be excelled; the only prominent change made is the increase of diameter, which for ordinary drilling is at present 8 in.

Who first used casing in a well? is a nut the lawyers are cracking at present.

Putting down a thin iron pipe of $5\frac{5}{8}$ in. diameter, below the lowest fresh water vein, and retaining the water by a seed-bag or water-packer, between the outside of the pipe and the wall of the well, enables the driller to proceed in his work without stoppage or annoyance, pouring in from the surface such water as he may need, and when the well is completed, to take his tubing in and out of the well at pleasure, still keeping the fresh water permanently from the oil-bearing sand.

In fact, the entire operations of drilling and pumping are carried on through the casing, and not until a well is finally abandoned is the casing drawn.

In this connection the Griffin water packer, Fig. 6, is a wonderful improvement on the bag of flaxseed formerly used; as will be readily seen, the weight of the column presses the leather against the sides of the well, forming an effectual stoppage; by means of a left-hand screw it can be loosened in a few minutes, and drawn out of the well

without difficulty; that anything so simple should avoid the miseries and expense long

Fig. 6.

attendant on the seed-bag, cannot fail to provoke a quiet laugh.

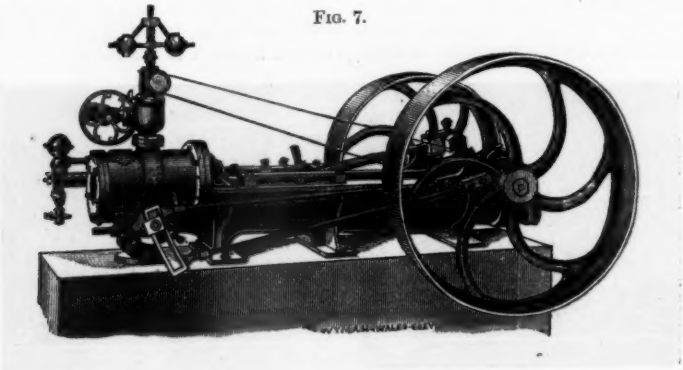
MOTIVE POWER.

Of the countless patterns of engines and boilers that flooded the oil country in 1865, not one has stood the test of time; those few from abroad who compete to-day in the trade, have been compelled to conform their work especially to its requirements.

The propensity of the oil producer to have everything made at home is hard to contend against, especially when it is supported by the spirit and enterprise of manufactories such as the "Titusville Manufacturing Co.," and the "Novelty Iron Works," two immense establishments and first-class in every way.

Fig. 7 is the plan of an engine, one of several styles, comprising in the main the most desirable features of a drilling engine, among which may be included, durable alignment, simplicity of construction, and an adjustable cut-off, permitting close economy in the use of steam; while it takes the

Fig. 7.



full power of an engine to drill and draw tools expeditiously, it requires but a small fraction of that power to pump, so that, when one boiler is furnishing steam to pump three or four wells, it is essential that each engine should take the minimum amount required. This is accomplished by a link motion of the etcentive, where, by adjusting the link, the steam will follow the piston from one-fourth to five-sixths of the stroke, working the balance of the stroke by expansion.

The engines now in common use are from 12 to 15 horse-power, the boiler from 15 to 20—to give ample steam for drilling and to pump a number of wells when completed; the steam-pipes to the several engines being covered by a wooden pipe, or boxed with some non-conductor of heat to prevent condensation.

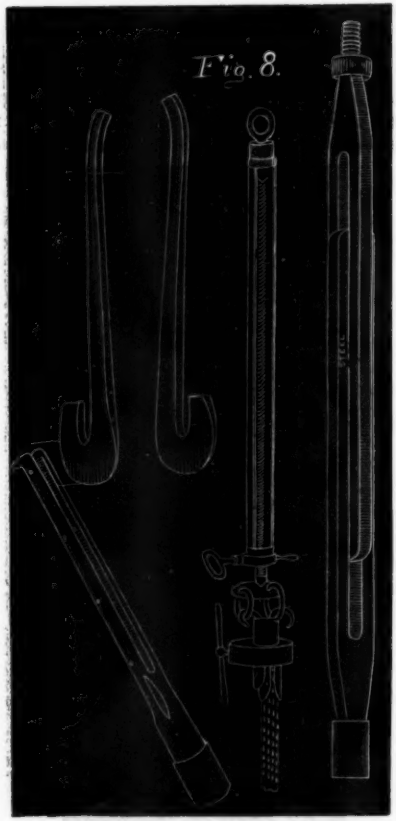
A very novel method of transmitting power to distant wells from one engine and boiler, is that of belting long distances by means of wire rope; it has been most successfully used by Mr. Stiles, of the "Volcano Oil Co.," West Virginia, in one instance running a well 600 ft. from the boiler, with a remarkably small loss for friction.

DRILLING TOOLS.

An old set of tools (unused) made in 1864, and weighing 300 lbs., were lately sold as old iron, in Titusville, for the sum of $15, the original cost being $350.

A set of tools to-day weighs from 1,800 to 1,900 lbs., and costs from $300 to $350.

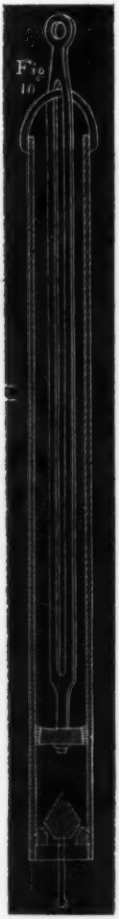
They consist of a temper screw, rope socket, auger stem, sinker-bar and substitute, the jars, two bitts, a round and flat reamer and two wrenches. (See Fig. 8.)



The temper screw varies little from former use except in size, the present total length being about 5 ft.; the details of its construction are fully shown by the cut. The auger stem, sinker-bar and substitute are respectively 24, 14, and 5 ft. in length; the substitute being used in starting the well.

They are made in the body of common round iron (2½ to 3 in.), with boxes and pins of Norway iron. Pins are 2¾ in. in length, 2¾ in. diameter, 8 threads to the inch, and with the least possible taper to prevent being loosened by the constant jar, which has also the tendency to crystallize the iron in the pins and boxes; making it necessary to renew them at intervals. The jars are made entirely of Norway iron (2 in. thick), with the exception of the inner faces and ends of the slotted openings, which are lined with steel; the whole being heated red-hot and carefully annealed to effect a thorough union of the metals. The stroke of the jars has been reduced to 12 in., and their total length is about 6 ft. The bitts are made of Norway iron with 40 lbs. of Sheffield steel on the point, which is drawn to a width of 5½ in., more or less, according to the depth of the well.

The flat and round reamers are made also

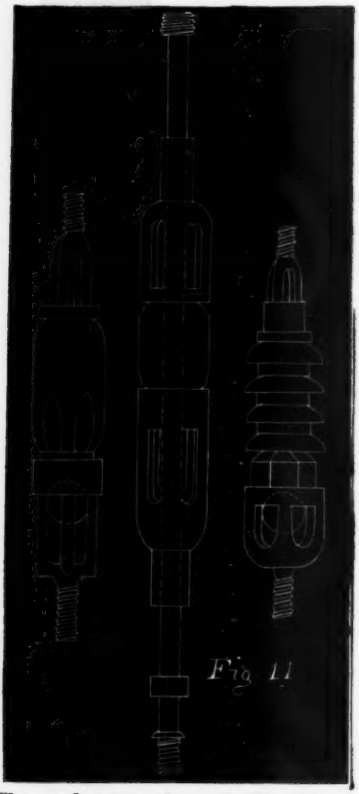


of Norway iron with more steel on the point. There are also extra tools for various purposes.

The hollow reamer (Fig. 9), for straightening a crooked hole, will explain itself. A spud or spoon for enlarging the well around a stuck tool, is simply half a hollow reamer; a slip socket, to drop over the head of a tool that is fast, with dogs or teeth to drop out and catch under the collar; a horn socket or tapering iron tube, to drive and wedge upon the head of any fastened iron,—all these, with many others, often specially devised and constructed for the occasion, are too numerous to be included in this paper.

The cable used is a 6 in. untarred manilla rope, only heavier than formerly, to meet the increased weight of the tools.

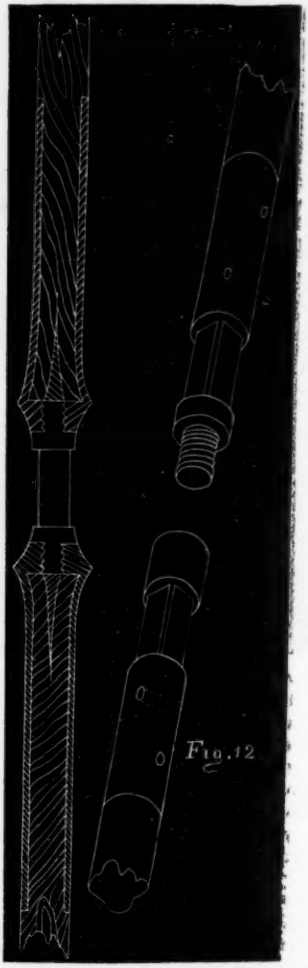
The wire rope has not yet been made that will answer for drilling purposes, as none are sufficiently pliable to use on the shaft of a bull wheel, and to increase the diameter of the shaft would cause loss of power.



The sand pump shown in Fig. 10 combines two advantages,—first, the valve with a drop-stem to open it on reaching the bottom of the well; and second, the piston, which keeps its place, at the bottom of the pump, while being lowered, but when drawn up, fills the pump by its suction with the loose sand and water.

PUMPING.

The main improvements under this head may be included in the two items of valves and sucker rods; without wishing to slight in the least the valuable pumps of various



kinds that are in use, the majority of wells are at present pumped with plain working;

barrels and valves, of which three styles are shown in Fig. 11.

The four-cup valve is quite durable and much used; it has four leather cups as shown, which can be renewed when worn; when gas is strong the second, or "Crocker" valve is preferred, the "Allen" valve next; it is a water-packer, and has been in use for years. The ordinary standing valve is placed as usual in the bottom of the working barrel.

The two styles of sucker-rod joints most used at present, are shown in Fig. 12. The rivets in the old fish-tail joints were constantly dropping into the working barrel; to remedy this, Mr. Innis gives us a joint without any rivets, where the wood is driven into the metal socket and widened with a wedge, and the joint of Mr. Hunt, made by driving the socket firmly into the wood, and passing two rivets in opposite directions; there being no cross strain on the rivets to tear off the heads, and the holes for the rivet in the socket being reamed with a flare, so that the head of the rivet does not project above the face of the socket, and therefore cannot be worn off by abrasion with the sides of the tubing; both are equally good rods, and satisfactory in every way.

The body of the sucker rod is made of the best upland ash, 1½ in. in diameter when dressed, and in length of from 24 to 28 ft.

To the casual reader all these things will appear as simplicity itself, and he will see little ground for the merit and skill that they claim to indicate; but if he was not in "oil" in 1865, he must remember that the pathway to this success, like all others, is strewn thick with failures—failures, too, so disheartening, that nothing but the purest grit backed with untold self-reliance could overcome.

As an instance of this, it may be stated that probably not less than five hundred different patterns of engines have been used in the region since the first well; and that the inventions upon every other branch of the subject are proportionately numerous, the records of the Patent Office will bear ample witness.

The next great problem that will engage the attention of oil-men, will be to overcome the great expense attendant upon the sinking and pumping of deep holes; until this is accomplished the extension of the south line of the Pennsylvania oil regions will daily become more difficult.

In conclusion, the writer desires to impress the fact that the special instances here presented are the successful result of years of thought and experiment in each particular case, that their value lies in that fact, and that they comprise, perhaps, the essence of modern artesian drilling.

To any one seeking for accurate details of the hundreds of auxiliary devices, a visit to the country itself would be essential and highly profitable.

WINDING ENGINES.

From "Engineering."

The rapidly increasing depth of many collieries makes it highly desirable that their winding arrangements should be as safe as economical, and some of our readers may therefore feel interested in a brief account of the rolling principles which are adopted in this respect in one of the greatest colliery districts of the Continent, namely, in Westphalia. The coal basin of the Ruhr comprised in 1870, 224 mines actually working, and giving employment to 52,160 miners. The quantity of coal raised, was 11,812,529 tons, worth £3,500,000 at the pit's mouth. The number of steam engines was 578, of 61,778 horse power; of which were employed in pumping, 199; winding, 304; pumping and winding combined, 28; in driving ventilators, 30; for coal-washing machinery, 13; and for man engines, 6.

A great number of the coal-pits, particularly in the northern districts, towards which the coal measures uniformly dip, have already reached a depth of over 150 fathoms, and are fast approaching the 200 fathoms level; such, for instance, are the mines, Oberhausen, Pluto, Nordstern, Courl, Margaretha, Hibernia, Von der Heydt, and others. Good and economical winding arrangements have consequently become for them a question of great importance, and all improvements are carefully watched and tried in the district. We may remark here, however, that the mines just mentioned, although undoubtedly deep, will scarcely

compare with many pits now being worked in this country, or with the still greater number of deep Belgian mines. For instance, there are in the Lancashire district the Pendleton, the Douglas Bank, and the Worthington pits, all about 300 fathoms deep, while there is the Dukinfield, with a depth of nearly 350 fathoms, and the Rosebridge Colliery, now the deepest mine in England, with a depth of 2,418 ft., or over 400 fathoms. In the Durham district there are several collieries, such as the Seaham, the Monkwearmouth, the Ryhope, etc., with depths of from 250 to 300 fathoms, while in Belgium the enormous depth of 3,489 ft. has been reached in the case of the Simon Lambert pit. This colliery is, however, we believe, not now being worked.

In order to facilitate the inter-communication of experience and the discussion of new arrangements, the mining engineers of Westphalia have formed themselves into an association—the Verein Tecnischer Grubenbeamten—which meets every two months in one or the other towns of the coal district, when papers on technical or other subjects of interest to coal mining are read and discussed. At the meeting held on February 18th last, at Dortmund, a paper was read by M. Erdmann, "On the more Recent Arrangements for Winding in Shafts," which found general approval, and of which we propose to give some particulars.

In selecting machinery for winding purposes in deep shafts, three principal matters have to be considered: 1. The possibility of raising a maximum of stuff. 2. The guarantee for obtaining the maximum of safety. 3. The greatest possible economical saving, or the minimum of expense. The quantity of stuff raised in a given time from a certain depth depends on the time required by the banksmen for running the tubs or wagons in and out of the cages, the speed of driving in the pit, and lastly, the quantity of coal to be raised with each draw or lift. The loading and unloading of the cages takes least time when the tubs can be placed in the cage side by side, and it is considered by M. Erdmann that in new pits the arrangements should be made so that four wagons can be placed on the same platform or deck, one pair behind the other. When the area of the shaft does not admit of such an arrangement, cages, with several tiers or decks must be employed, but then special platforms should be provided for every tier to allow all tubs to be run out simultaneously, and to avoid a repeated lifting or lowering of the cage at each draw. The signals, which are used to communicate between the bottom and the bank, are of considerable importance for shortening the time during which the winding machinery is standing still; electric signalling apparatus, such as that of Dr. Gurlt, having the preference. The driving speed in the shafts has in many instances reached 30 ft. a second, and it appears that this is considered near the obtainable maximum, so that little more can be expected in that direction, if regard be paid to the necessary safety. However, the quantity of stuff raised at each draw can, in most cases, be advantageously increased; as, compared with the dead weight of the cage, rope, and tubs, it forms only a small fraction of the whole weight. This dead weight, M. Erdmann considers, can be materially lessened by the use of tapering pit ropes, and many existing engines could thus be made capable of lifting a larger amount of coal than they can do now with even ropes.

The facility of starting the engine has again a great influence on the maximum lifting power obtainable. With powerful engines, lifting valve gear is, in the Ruhr district, generally preferred to slide gear, the latter requiring too much power, and the arrangements with a supplementary steam cylinder for reversing, etc., which is very well for heavy marine engines, having ended in failure with winding engines. The valves are occasionally also a source of annoyance, particularly when they stick, in consequence of water having found access to them; however, this can be avoided by adopting suitable arrangements of discharge valves. The rotating parts of the machinery, M. Erdmann considers, should be constructed as light as possible, in order to lessen the *vis viva*, and to facilitate the stopping of the engine in the shortest possible time. It is very important that all parts of the engine should be seen by the driver, and horizontal engines, offering the greatest advantage in this respect, have been generally adopted in the Ruhr district. The diameter of cylinders should be great—36 in. to 42 in. seems to touch the advantageous maximum—and the engines should be direct-acting. With new shafts two engines should always be employed, as is the case in the Saar district, one acting as a reserve, and being generally used only for

the transport of the miners. The greater security in working the shaft, and the time saved for raising coal by the ordinary engine, amply repays the increased outlay. The steam to be used must be raised to 5 or 6 atmospheres, and the boilers constructed accordingly.

With regard to the greatest possible safety in pit winding, a rigorous supervision of the shaft and engines is the chief requirement, as most accidents can be traced back to irregularities in the shaft, or the carelessness of the engine driver. The elasticity of the pit ropes is also a condition of safety. Inelastic and brittle ropes are entirely inadmissible, as from even small hindrances in the pit they are subjected to shocks, the important action of which few have considered, but which, however, can be readily calculated. Steel ropes, offering up to their breaking load only an elongation of 4 per cent. as compared with iron ropes, which will allow 20 per cent., are considered by M. Erdmann to give less safety, and the latter should be preferred. Their flexibility has a great influence on the wear and tear. Ropes made from hemp, or aloe fibre, are more flexible than iron ropes; they compare, however, to their disadvantage for their less strength in proportion to their weight. The flexibility of iron ropes can be increased by using very thin wire, and a diameter of 5 millimetres (= about 0.2 in.) should not be surpassed. For the same purpose the diameter of the drums, and sheaves, or pulleys, may be increased; the former are generally in the Ruhr district not less than 17 ft., and the latter 10 to 12 ft.; however, for the sheaves it is commendable to give a greater diameter. It is a rule to give to drums and sheaves a diameter 1,000 times greater than that of the wire, that is for 5 mill. wire 16½ ft. The groove of the sheaves is best turned after the sheaves are mounted in their frames, in order to offer the least friction to the rope.

The guides down the shaft are to be fastened with great care, screw bolts being used. As most of the safety catches, as those of Calow, Libotte, White, and Grant, etc., are constructed with claws, the guides are generally made of timber; however, M. Erdmann considers that guides of iron rails are preferable, and they allow the application of Hoppe's safety catch with wedge brake, which has proved to be a great success, and does not arrest the falling cage with a sudden grip in the timber, but by a gradual and sure action of the wedges upon the iron guide. The cage is thus brought to a stand-still without any violent concussion, in the same way as the speed of a railway train is lessened. In order to avoid overwinding, the pit-head frames have to be made sufficiently high; or between the rope and the connecting chains of the cage, claws or shears are to be applied, which will open at a certain height above the bank, or a self-acting steam brake may be used, in which case the brake ring should act direct upon the winding drum, in order to avoid the strain on the crank shaft.

As regards the construction of the driving engines, twin-engines with horizontal cylinders merit the preference before all others, particularly before beam engines. Attention must be paid that their foundations are very strong; a height of 12 ft. will be sufficient in most cases. The use of large blocks of stone is not anywhere so much followed as formerly, masonry in cement being much substituted for them; however, this should not go too far. M. Erdmann recommends that good solid blocks of hewn stone should at all events be used for the fastening of the foundation bolts, it being a well-known fact that cement loses much of its tenacity when frequently exposed to the action of fatty or oily matters. It is well to use horizontal bolts besides, to keep the foundations firmly together. The frame of the engine, M. Erdmann considers, should be made of wrought iron, for its greater strength and elasticity, which make the occasional breaking of the frames less probable than if they were made of cast iron; however, frames of the latter material may be admitted, provided that they are sufficiently strong. The chief foundation bolts should not stand vertically, as was formerly the custom, but they should diverge downwards, and thus gain a greater resisting surface. Many working parts of the engine, piston-rods, levers and bolts are now made of cast steel; M. Erdmann, however, does not consider it advisable to construct the main crank shaft of that material, because cast steel worked out in such large blocks readily loses its strength. Wrought-iron shafts for engines with spiral drums, constructed for a depth of 250 fathoms, should not be less than 1 in. diameter, as the shaft should not only offer sufficient guarantee against breaking,

but should not bend in the least, a failing which would be indicated by the bearings running hot. The adoption of double eccentrics for forward and backward gear is necessary to regulate the retardation. The piston is to be guided by the rod which passes through a stuffing-box in the back cover, and rests on a slide block. As a matter of course, the care of the engine must only be confided to really reliable persons, and the expense for an auxiliary engine-driver should never be feared when a great amount of regular and good work is required.

As to the economy of winding in shafts, M. Erdmann remarks that it may be taken as generally true that the most expensive arrangement proves itself to be the cheapest in the long run; however, a perfect compensation of the weight of both ropes is the principal condition for economical pit winding. This compensation may be approximately effected by the use of flat ropes, and a minimum diameter of the rope-roll or drum of 42 in., while conical drums with inclined sides of 30 deg. are hardly more economical to a depth of 100 fathoms. For any depth above that, spiral drums are to be recommended, and they offer an advantage of 25 per cent. in fuel over all other systems, when combined with direct-acting engines, and worked with expansion gear. A few condensing engines are still in use for winding purposes in the district of which we have been speaking; and it is considered by M. Erdmann to be an open question, whether condensation could not be reintroduced with advantage wherever condensing water is to be had, particularly so as some of the older engines have given very fair economical results. To avoid the drowning of the air-pumps while the engine stands still, a separate steam-pump has been used with advantage, and future trials may still be recommended in that direction.

SKETCH OF THE PLANS AND PROGRESS OF THE DETROIT RIVER TUNNEL.*

By E. S. CHESBROUGH.

The first suggestion of a tunnel under the Detroit River† for railroad purposes was made to me about five years since by Mr. James F. Joy, President of the Michigan Central Railroad, with the request that the feasibility of the project might be ascertained as soon as convenient. In January, 1869, a report, accompanied by plans and estimates, was presented to that gentleman. From these are taken most of the statements in this paper, so far as they relate to what was done previous to the actual commencement of the work.

In the preliminary examinations the first attempt was made to get a line at right-angles with the river, not only across the stream itself but between the extremities of the approaches on each side. To avoid as far as possible damages to valuable property, the lower side of the city was selected. But boring showed very unfavorable ground there, and as the bed rock in that vicinity lies too near the surface for convenience, and is still nearer lower down the stream, further operations were necessarily confined either within the limits of the city or above it.

Careful examinations were made above the line first surveyed, by boring on each side of the river. When good ground was found on each side at points opposite each other, borings were made in the river between; but it was not until the vicinity of the Detroit and Milwaukee Railway Depot was reached, that ground considered safe, entirely across the river, was met with.

A perfectly feasible line could be obtained entirely above the city, where the ground is very favorable; but in consequence of a greater length of tunnel and considerably longer new track being required, nothing could be saved in expense by it, and much lost in convenience; for the line adopted makes the utmost possible use of existing depot grounds of the Michigan Central Railroad on the Detroit side, and will not require a great sacrifice of the station buildings and tracks of the Great Western Railway on the Canada side. These two companies are the parties most interested in the enterprise.

The line as finally determined upon com-

* A paper read before the American Society of Civil Engineers.

† All who are familiar with the Detroit River know that at the particular point where the tunnel is located, it is about half a mile wide, and runs from west to east or very nearly so.

mences at the Michigan Central Railroad passenger station, passes for a considerable distance along Jefferson avenue under the southwest corner of the Biddle House and the east end of the freight house of the Detroit and Milwaukee Railway, crosses to the other side of the river about half a mile above the terminus of the Great Western Railway, and unites with that road about one and a half miles further on, making the entire length of track between the two roads a little less than three miles. The length of tunnel is to be about 8,600 ft. (3,000 of which is under the river). The least curvature on this portion of the line is 2,300 ft. radius, and the steepest grade, 1 in 50.

Although the borings indicated favorable ground along the line adopted, except that possibly there might be a very troublesome amount of water from land springs, or springs having their source higher than the river, it was deemed prudent to avoid all risks as far as possible in planning the details of the work. For this reason, it was determined to have not less than 20 ft. of roof between the top of the masonry and the bottom of the river. In no case, as far as could be ascertained, would there be less than 12 ft. of stiff clay immediately above the tunnel.

To diminish the risk still further, it was determined to make two single track tunnels, circular in form, with eighteen and a half feet interior diameter, instead of one large enough for a double track. By careful estimates, the first was found to be no more expensive than the other. Besides, for some years, one track would probably be sufficient, perhaps long enough for the saving of interest to build another—at least to go far towards it. This size of tunnel was adopted to give room enough for the largest Pullman car on either of the connecting roads.

The circular form was adopted, because of its greater safety in case a soil should be met with disposed to swell like the London clay. Mr. Storrow, in his Hoosac Tunnel Report, describes a case of this kind, in which, after two attempts to line a tunnel of the usual or horse-shoe form, with masonry, the circular form was finally adopted. The lining is to be of brick masonry, laid in cement, generally 24 in. thick under the river and 18 in. on land.

It is proposed to place the two tunnels so far apart under the river, that in case the second one should be delayed till after the completion of the first, an accidental cave would not endanger the stability of the one in use.

Experience in the construction of the river tunnels in Chicago teaches not only the convenience, but the necessity of a drainage tunnel for a least half the distance across the river, in a work like this. It has been thought best to make it entirely across the river for the Detroit tunnel, and for the following reasons:

First.—It would be of great convenience and value, if much water should be encountered in the construction of the main tunnels.

Second.—It would serve a very valuable purpose as a reservoir, should the machinery for pumping out the main tunnels happen to be disabled at the commencement of a great flood of rain falling in the open approaches at the ends of the tunnel, an occurrence that has taken place already more than once in Chicago.

Third.—As the main tunnels must necessarily be curved part of the way under the river on each side, the drainage tunnel, after its completion, would form a most satisfactory base of alignment.

Fourth.—The shafts at each end of it could be made to serve as working shafts for the main tunnels during their construction, and for ventilating purposes afterwards, should that be found necessary.

Fifth.—A reason that did not occur originally, but is now quite apparent: it would afford the means of shortening the time necessary to complete the main tunnels under the river, and consequently the whole work one-half. This could be done by commencing operations at two points under the river, equidistant from each other and from the shore shafts. In this way, six working faces instead of two could be obtained, so that an average progress from each face of but 2 ft. a day would insure the completion of the work in something less than a year. Of course, on each side of the river as many shafts could be sunk as might be found necessary to complete the land portion of the work as soon as that under the river.

The open approach on the Detroit side fortunately occurs in a wide avenue, and is situated between two streets, so that very little, if any, inconvenience will result to the public travel. It will be 26 ft. wide, with vertical retaining walls on each side. The

Canada approach occurs in an open plain, and will be a simple earth excavation, except at and near the portal, which is to be in 57 ft. depth of cutting.

The estimated cost of the whole work is $2,650,000. This estimate was based upon the supposition that no machines would be used in removing the earth except to hoist it up the shafts. It was thought, however, that machinery operated by compressed air could be used, and diminish considerably the cost of the work. If one quarter of the advantages claimed in the "London Times" of January 18th for Brunton's machine, now seriously proposed for boring under the Straits of Dover, can ever be realized, the cost of tunnelling through firm ground will be greatly diminished.

It was recommended that the drainage tunnel be constructed before soliciting proposals for the main work, so that contractors might feel more certain of the nature of the ground, and thus be disposed to make lower bids than they otherwise would. This recommendation has been adopted by the companies chartered both in Michigan and in Canada.

Both shafts have been sunk to the bed rock. On the Detroit side this reaches to the bottom of the sump, or about eight and a half feet below the bottom of the drainage tunnel. On the Canada side the bed rock is only two feet below the bottom of the drainage tunnel, and the sump will be sunk a few feet in it. From the Detroit shaft the drainage tunnel has been carried a little more than 600 ft. out under the river, and from the Canada shaft a little less than 100 ft., or about 700 ft. in all. The Canada shaft was not commenced for several months after the Detroit one was begun.

The rate of progress in this work has thus far averaged not more than one half that which was expected, owing to the very hard ground, composed partly of boulders. On neither side of the river, however, does the layer of boulders extend so high up as the bottom of the main tunnel, and only a few feet of its lowest portion will be in hard-pan. The ground passed through in each shaft shows a great correspondence in position and character, from which it is inferred that the excavation of the main tunnels, under the river especially, will be through a stiff but easily worked blue clay. The fact that a seam separating two slightly different kinds of earth has been in sight most all the way thus far from the Detroit shaft, confirms the belief that across the river the different layers of earth, except when cut away by the stream, are uniform in thickness down to the hard-pan, and dip slightly towards the south.

The principal precautions deemed important in the prosecution of the main work are these:

First.—To require the contractors to have constantly a force composed, in part at least, of skilled laborers accustomed to mining in difficult ground, should it be met with.

Second.—The use of a skeleton shield of iron or steel, which in case of necessity could be fitted out in front and around the sides of the excavation in advance of the masonry.

Third.—Frequent probings or borings in front and on the sides, to give warnings of the proximity of bad ground. Even should there be no difficult ground to pass through, these borings would probably prove a safeguard in drawing off large volumes of gas gradually, and thus prevent serious, if not fatal, explosions. This course was found advisable in the construction of the Chicago Lake Tunnel.

Fourth.—The use of a large tarpaulin on the bottom of the river immediately over the workmen. This was successfully used, if my memory is correct (the late fire in Chicago destroyed my books of reference), in passing a breach that had been filled with bags of sand in the Thames Tunnel, and it is believed could be equally useful in preventing a breach. It would require the employment of divers, who could also be very usefully occupied a great part of the time in probing the bottom of the river just in advance of the work to discover any deep pits or pockets of sand or silt that might exist.

The question has often been asked if it would not be cheaper and better to construct a bridge across the river at Detroit than to make a tunnel under it? Some engineers have looked into the probable cost of a bridge, and believe it would be preferable, both on account of the greater economy in cost of construction and in maintenance afterwards; but this question has been set at rest for the present by the absolute refusal of the Canadian Parliament to grant a charter for a bridge so long as a tunnel is considered practicable.

Mr. Charles H. Fisher: I would ask Mr. Chesbrough if he would favor the use of the

same tools and methods with which he made the borings?

Mr. Chesbrough: The borings were made with a wood auger,* such as I used in the construction of the lake tunnels here in Chicago, with which specimens from different depths were brought up. Of course, there was doubt whether these always came from the depth to which the auger was sent down, but we found afterwards that it was so in every case. The material which was drawn up with the auger came from the point where the auger ceased to be turned round. In Detroit we have practically relied upon this; but where, however, there is doubt, it would be best to sink a tube such as is put down for artesian wells; but little of which has been done. The auger we used was one and a quarter or one and a half inches in diameter, and is large enough if the joints are properly made. A very good quality of iron is required to withstand the torsion.

A Member: Will the material always stick to the auger if hauled through water?

Mr. Chesbrough: Not if it is very soft. In such cases we used a tube made of wrought iron; but when the auger stopped in stiff clay we could rely upon it.

A Member: Did you have to remove the auger frequently?

Mr. Chesbrough: We generally drew it up once in about 10 ft., and it usually brought up the whole strata. In some instances we could not remove more than 6 in. of the strata, but it was very seldom.

A Member: I understand that you bored that way to a depth of 90 ft.?

Mr. Chesbrough: Yes; sometimes 80 or 90 ft. were bored in a little over a day; again, to get a satisfactory boring it would take a week. Occasionally a boulder would be hit and the rods broken. Of course the rod was very long, so that one would think it would break in turning, but it did not.

Question: If you struck a boulder rock you would not succeed?

Mr. Chesbrough: Of course not; boulders would stop progress in that place, but we would try in another.

THE INTENSITY OF SOLAR RADIATION DEMONSTRATED.

By CAPTAIN JOHN ERICSSON.

From "Engineering."

The illustration on page 367 represents an instrument by means of which the intensity of solar radiation at the surface of the earth has been determined with absolute certainty. The computations published by the writer, showing that the temperature of the surface of the sun exceeds 4,035,500 deg. Fahr., being based solely on the indications of the actinometer delineated and described in "Engineering," Sept. 30, 1870, that question has been raised whether the instrument is reliable. It is urged that part of the indicated temperature may be the result of heat radiated towards the bulb of the thermometer by the surrounding casing. Some scientific men also contend that, while the dynamic energy transmitted by the sun's rays may be accurately measured by ascertaining the number of thermal units developed in a given time on a given area, the *temperature* produced by solar radiation cannot be determined, owing to the unknown influence of the surrounding medium, a plausible argument which will be disposed of by the following demonstration. Suppose a small spherical body of perfect conductivity to be suspended within a large inclosure provided with a perforation in the direction of the sun, of sufficient size to admit a pencil of rays (a sunbeam) of the same diameter as the sphere. Suppose, also, that the temperature of the sphere is 64 deg. higher than the temperature of the inclosure and the air contained within the latter. The convex area of a sphere being four times greater than the area of its great circle, while the great circle of the sphere which we have imagined corresponds exactly with the sectional area of the sunbeam entering through the perforation of the inclosure, it will be evident that the supposed excess of temperature, 64 deg., cannot be maintained unless the radiant energy of the sun's rays be four times greater for corresponding area than the radiating energy of the sphere. It will also be evident that, if the assumed excess of temperature of the sphere gradually falls while exposed to the sun's rays, until it is reduced to 16 deg. above the temperature of the inclosure,

* Like that commonly employed for boring wood.

then the intensity of the sun's rays cannot be more than 4×16=64 deg. Bearing in mind that the section of the sunbeam which transmits the energy is only 0.25 of the convex area of the radiating sphere which receives the heat and, in turn, radiates that heat towards the inclosure, we cannot question the correctness of the deduction that, assuming the rays to be parallel, the intensity of the radiant energy which enters through the perforation of the inclosure is four times greater than that which the radiating sphere parts with. Again, the intensity of the radiant heat of solid bodies being a correct index of dynamic energy, it will be perceived that the energy transmitted to the inclosure by the radiating sphere at a differential temperature of 16 deg. will be exactly balanced by the energy transmitted by the sunbeam at 64 deg. entering through the perforation of the inclosure, the section of which is 0.25 of the convex area of the sphere.

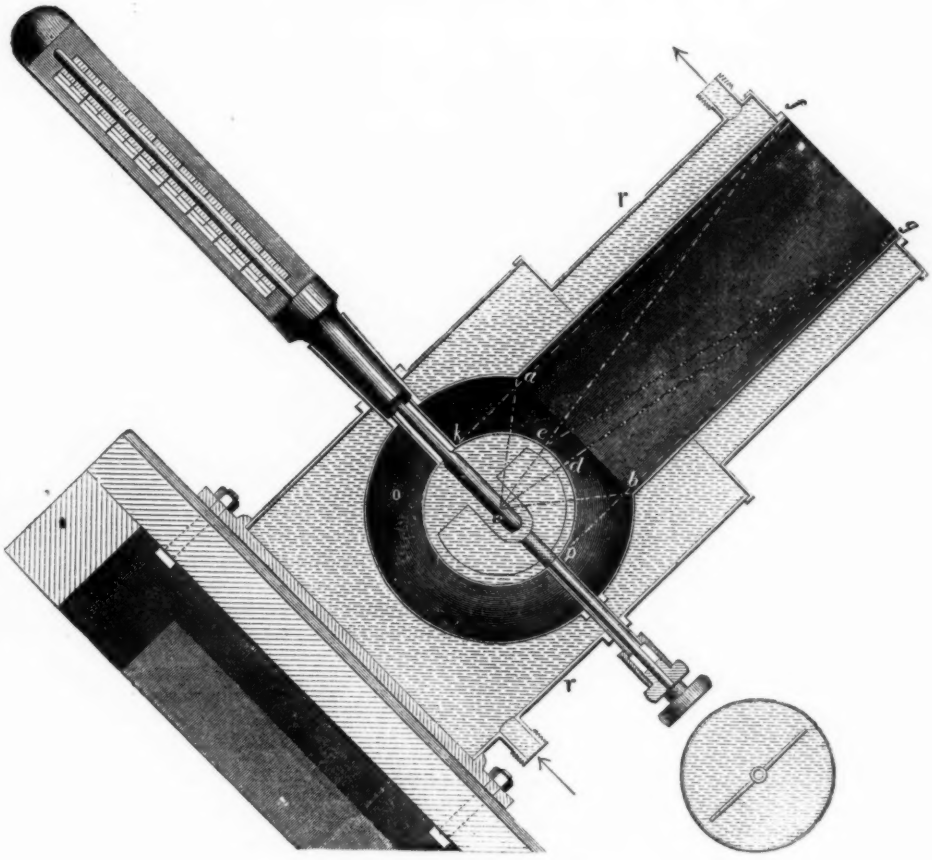
The demonstration thus presented, it will be admitted, establishes the important fact that the temperature produced by solar radiation is four times higher that the differential temperature of a small sphere, composed of materials of perfect conductivity, exposed to the sun, and permitted to radiate freely towards an inclosure of great extent and uniform temperature.

Let us now examine the instrument before referred to, shown by our illustration, which represents a section through the central vertical plane: *k p* is a spherical vessel composed of copper, charged with water and coated with lamp-black, suspended within a spherical inclosure, *o*. The latter is provided with a circular perforation, *a*, *b*, to which a diagonal cylindrical trunk, *a*, *g*, is attached, the spherical inclosure as well as the trunk being coated with lamp-black on the inside. A thermometer provided with a cylindrical bulb, *c*, is inserted diagonally into the spherical vessel; and also a rotating paddle-wheel, operated by an axle passing through a water-tight stuffing-box. A cylindrical vessel, *r*, *r*, filled with water, surrounds the spherical inclosure and trunk, nozzles being applied at the top and bottom, to which flexible tubes are attached for passing a current of cold water through the vessel. The instrument is mounted within a revolving observatory, and attached to a table turning on declination axis provided with appropriate mechanism, by means of which it may be directed towards the sun.

It will be evident that, if the axis of the trunk, *a*, *g*, be pointed accurately towards the centre of the sun, the sphere, *k*, *p*, will receive the whole radiant energy of the sunbeams within the tangential lines, *k*, *f* and *p*, *g*, the sectional area, as before stated, being 0.25 of the convex area of the sphere. It will be evident also that, owing to the perforation, *a*, *b*, the sphere, *k*, *p*, will not be acted upon by the full amount of refrigeration produced by the radiation of an uninterrupted inclosure. Agreeably to the theory of exchanges, the deficiency will, however, not be great, since the side, *f*, *a*, of the diagonal trunk will radiate as powerfully towards the sphere as a portion of the spherical inclosure corresponding with the angular distance determined by the radial lines, *a*, *c* and *f*, *c*. But the convex surface of the segment, *e*, *d*, determined by the angle subtended by *f*, *c* and *g*, *c*, will obviously be subjected to far less refrigeration than an equal surface on the opposite side of the sphere. Regarding the exact amount of deficient refrigeration consequent on the perforation of the inclosure at *a*, *b*, it will be perceived on reflection that the radiation of the inclosure towards the semi-spherical surface presented to the sun, will be reduced in the exact proportion which the convex surface of the segment, *e*, *d*, bears to the area of the great circle of the sphere. It will be seen, therefore, that although the condition coupled with our proposition has not been complied with, namely, that the inclosure (in order to render the area of the perforation inappreciable) should be of great extent compared with the size of the radiating sphere, yet the small capacity of the spherical inclosure of our instrument and the comparatively large perforation at *a*, *b*, will not materially reduce the radiating power of the inclosure. Besides, the known angle subtended by the radial lines, *f*, *c* and *g*, *c*, enables us, as shown, to calculate the exact amount of deficient radiating surface presented by the inclosure.

Several experiments have been made simultaneously with the instrument now illustrated, and the actinometer, in order to ascertain the precise relation between the temperature transmitted by the sun's rays to the radiating sphere, and to the actinometer the accuracy of which has been questioned. Both instruments have invariably been attached to the same declination table during the investigation, consequently the

radiant heat transmitted to each has been precisely alike. Respecting the instituted test, it will suffice to record the result of an experiment conducted at noon, October 20, 1871, the solar radiation on that day being of nearly average intensity, while the sun's zenith distance, 51 deg. 40 min., was also near an average. Observations made at equal intervals of 5 min., from 11 hours 55 min. A. M. to 12 hours 30 min., showed that the radiating sphere of the instrument, the contents of which were effectually agitated by the internal paddle-wheel, attained a temperature of precisely 75 deg., while the



inclosure was maintained (by a continuous stream of water) at a constant temperature of 61.3 deg. Accordingly, an excess of temperature of 13.7 deg. above that of the inclosure was produced by the solar radiation acting freely on the sphere, the actinometer, at the same time, indicating a temperature of 51.36 deg. Now, agreeably to our theory, the temperature of the sphere ought to have been 51.36÷4=12.84 deg., thus showing a discrepancy, an excess, of 13.7 – 12.84=0.86 deg. It has already been explained that the sphere does not receive a full amount of refrigeration, in consequence of the perforation of the inclosure necessary to admit the diagonal trunk; hence, the in-

Table showing the Temperature produced by Solar Radiation at the Boundary of the Earth's Atmosphere for each day in the year, together with the diurnal increase and diminution of Solar Intensity occasioned by the varying distance between the Sun and the Earth.

Date.	January.		February.		March.		April.		May.		June.		July.		August.		September.		October.		November.		December.	
	Maximum.	Difference.	Maximum.	Difference.	Maximum.	Difference.	Maximum	Difference.	Maximum.	Difference.	Maximum.	Difference	Maximum.	Difference.	Maximum.	Difference.	Maximum	Difference.	Maximum.	Difference.	Maximum	Difference,	Maximum.	Difference.
1	90.72	5.88	90.28	5.44	89.27	4.43	87.77	2.93	86.32	1 48	85.22	0.38	84.84	0.00	85.22	0 38	86.32	1 48	87.77	2.93	89.27	4 43	90 33	5.49
2	90.72	5.88	90.25	5.41	89.22	4 38	87.72	2 88	86.27	1.43	85.20	0 36	84.84	0.00	85.25	0.41	86.36	1.52	87.82	2.98	89.31	4.47	90.36	5.52
3	90.71	5.87	90 22	5.38	89.18	4.34	87.67	2.83	86.23	1.39	85.18	0.34	84 84	0.00	85.28	0.44	86 41	1 57	87.87	3 03	89 35	4.51	90.38	5.54
4	90 71	5.87	90 19	5.35	89.13	4.29	87.62	2.78	86.19	1.35	85 15	0.31	84.84	0.00	85.31	0.47	86.45	1 61	87.92	3.08	89 39	4.55	90.40	5 56
5	90.70	5 86	90.16	5.32	89 09	4.25	87.57	2.73	86.15	1.31	85.13	0.29	84.85	0.01	85 34	0 50	86.50	1.66	87.97	3.13	89 43	4.59	90.42	5.58
6	90.70	5.86	90.13	5.29	89.04	4.20	87.52	2.68	86.11	1 27	85.11	0.27	84.85	0.01	85.37	0.53	86 54	1.70	88 02	3.18	89.48	4.64	90.44	5.60
7	90.69	5 85	90.10	5.26	89.00	4.16	87.47	2.63	86.07	1.23	85 09	0.25	84 86	0.02	85.40	0.56	86.59	1 75	88 07	3 23	89.52	4.68	90.47	5 63
8	90 69	5 85	90.07	5.23	88.95	4.11	87 42	2.58	86.03	1.19	85.07	0.23	84.86	0.02	85.43	0.59	86.64	1.80	88.12	3.28	89.56	4.72	90 49	5.65
9	90.68	5.84	90.04	5.20	88.91	4.07	87 37	2.53	85 99	1 15	85.05	0 21	84.87	0.03	85 46	0 62	86.68	1 84	88.17	3.33	89 60	4.76	90.50	5 66
10	90.67	5 83	90.01	5.17	88.86	4 02	87.32	2.48	85.95	1.11	85.03	0.19	84.87	0 03	85.49	0.65	86.73	1 89	88.22	3.38	89 64	4.80	90.52	5.68
11	90.66	5.82	89.97	5.13	88.81	3.97	87.27	2.43	85.91	1.07	85 02	0.18	84.88	0.04	85.52	0 68	86 78	1.94	88.27	3.43	89.68	4.84	90.54	5.70
12	90.65	5.81	89.94	5.10	88.76	3 92	87.22	2 38	85 87	1.03	85.00	0.16	84 89	0 05	85 55	0.71	86.83	1.99	88 32	3 48	89 72	4.88	90 56	5.72
13	90.64	5.80	89 90	5.06	88.71	3 87	87 17	2.33	85.83	0 99	84 99	0.15	84.90	0 06	85.58	0.74	86.87	2 03	88 37	3.53	89.76	4.92	90.57	5.73
14	90 63	5 79	89.87	5.03	88.67	3.83	87.12	2.28	85 79	0.95	84 97	0.13	84.91	0.07	85.61	0.77	86 92	2 08	88.42	3 58	89.79	4 95	90.59	5.75
15	90.62	5.78	89.83	4.99	88.62	3.78	87.07	2.23	85 76	0 92	84 96	0.12	84 92	0.08	85 65	0.81	86.97	2.13	88.47	3 63	89.83	4.99	90.61	5.77
16	90.61	5.77	89.79	4.95	88.57	3.73	87 02	2 18	85 72	0 88	84.94	0 10	84 93	0.09	85.68	0 84	87 02	2 18	88 52	3.68	89.87	5.03	90.62	5.78
17	90.59	5.75	89.76	4.92	88.52	3 68	86.97	2.13	85.68	0 84	84 93	0 09	84.94	0.10	85.72	0.88	87 07	2.23	88.57	3 73	89.90	5 06	90.63	5.79
18	90.57	5 73	89.72	4.88	88.47	3.63	86.92	2.08	85.65	0 81	84.92	0 08	84.96	0.12	85 76	0.92	87 12	2.28	88.62	3.78	89.94	5.10	90.64	5.80
19	90.56	5.72	89 68	4.84	88.42	3.58	86.87	2 03	85 61	0.77	84.91	0 07	84.97	0.13	85.79	0.95	87.17	2.33	88.67	3.83	89.97	5.13	90.65	5.81
20	90.54	5.70	89.64	4.80	88.37	3.53	86.83	1.99	85.58	0 74	84.90	0.06	84.99	0.15	85.83	0 99	87.22	2 38	88.71	3 87	90 01	5.17	90.66	5.82
21	90.52	5 68	89 60	4.76	88 32	3.48	86.78	1.94	85 55	0 71	84.89	0.05	85.00	0.16	85 87	1.03	87 27	2.43	88.76	3 92	90 04	5.20	90 67	5.83
22	90 50	5 66	89.56	4.72	88.27	3.43	86.73	1.89	85.52	0.68	84.88	0.04	85 02	0 18	85.91	1.07	87.32	2 48	88.81	3 97	90.07	5.23	90.68	5 84
23	90.48	5 63	89.52	4.68	88 22	3.38	86.68	1.84	85.49	0.65	84 87	0.03	85 03	0.19	85.95	1 11	87.37	2 53	88.86	4.02	90.10	5.26	90.69	5.85
24	90.46	5.60	89.48	4 64	88 17	3.33	86 64	1.80	85.46	0.62	84 87	0 03	85.05	0 21	85 99	1.15	87.42	2.58	88.91	4.07	90.13	5.29	90 69	5 85
25	90.44	5.68	89 43	4.59	88.12	3.28	86.59	1.75	85.43	0 59	84.86	0 02	85.07	0.23	86 03	1.19	87.47	2 63	88.95	4.11	90 16	5.32	90 70	5 86
26	90 42	5.56	89.39	4 55	88.07	3.23	86.54	1.70	85 40	0.56	84.86	0.02	85.09	0.25	86 07	1 23	87.52	2.68	89.00	4.16	90.19	5 35	90.70	5.86
27	90.40	5.54	89 35	4 51	88.02	3.18	86 50	1.66	85.37	0.53	84 85	0 01	85.11	0 27	86.11	1.27	87 57	2 73	89.04	4 20	90.22	5 38	90.71	5.87
28	90.38	5.52	89.31	4 47	87 97	3.13	86 45	1.61	85.34	0.50	84 85	0 01	85 13	0.29	86.15	1.31	87 62	2.78	89.09	4.25	90.25	5.41	90.71	5.87
29	90.36	5.56	....	.. .	87.92	3 08	86 41	1 57	85 31	0.47	84 84	0.00	85 15	0 31	86.19	1 35	87.67	2 83	89 13	4.29	90.28	5.44	90 72	5.88
30	90.33	5.49	....	....	87 87	3.03	86.36	1.52	85.28	0.44	84 84	0.00	85.18	0.34	86.23	1 39	87.72	2 88	89.18	4.34	90.30	5.46	90.72	5.88
31	90.30	5.46	....	....	87.82	2.98	....	....	85.25	0 41	....	....	85.20	0.36	86.27	1.43	....	....	89.22	4.38	....	....	90.72	5.88

dicated temperature of the sphere should exceed that which our theory has established. The observed excess, 0.86 deg., is, however, greater than it should be in accordance with the relative magnitude of the convex surface, *e*, *d*, and the area of the great circle of the sphere. Referring to the illustration, it will be seen that, at the point where the thermometer is inserted, a considerable portion of the convex surface of the sphere is not subjected to the radiation from the inclosure; nor at the point where the axle of the paddle-wheel enters. Adding these surfaces to that of *e*, *d*, the amount of cold radiation, prevented from acting on the sphere, will be found to correspond so nearly with the excess of temperature observed, that we are warranted in asserting that the temperature indicated by the actinometer during the experiments has proved to be exactly *four* times higher than that of the sphere exposed to the radiant power of the sun's rays, and to the refrigeration caused by the radiation from the inclosure. Our introductory demonstrations having shown that the temperature produced by solar radiation is four times higher than the temperature imparted to a sphere exposed to the sun, and permitted to radiate freely in all directions towards an inclosure of low temperature, the test instituted October 20, 1871, proves positively that the indications of the actinometer are correct.

Referring to the tables previously published in "Engineering," * it will be seen that the maximum intensity of solar radiation in lat. 40 deg. 42 min., ascertained by the actinometer, is 66.2 deg. when the earth passes the aphelion. And that, owing to diminished atmospheric depth consequent on diminished zenith distance, the maximum intensity of solar radiation on the ecliptic reaches 67.20 deg. when the earth is furthest from the sun. Now, by a series of actinometric observations of the temperature produced by solar radiation at various zenith distances, from 17 deg. 12 min. to 75 deg., I have ascertained that the retardation suffered by the sun's radiant heat in passing vertically through the atmosphere amounts to 17.64 deg. Consequently, the intensity of solar radiation at the boundary of our atmosphere when the earth is in aphelion, will be nearly 85 deg. Fahr. Future investigations will, no doubt, confirm the exactness of this determination of the intensity of the radiant heat at a distance of 218.1 semi-diameters from the centre of the sun. The dispersion of the rays at this distance, it should be borne in mind, is so great that the heat emitted by one square foot of the solar surface is distributed over 218.1^2=47,567 sq. ft. of the surface of the earth. The fact that, notwithstanding such extreme dispersion, the temperature produced by solar radiation reaches a thermometric interval of 85 deg. on the Fahrenheit scale, proves the fallacy of the demonstration recently published by the French *savants*, showing that the temperature of the surface of the sun does not exceed that which a chemist readily produces in his laboratory.

The accompanying table is the result of observations continued for several years. It is based on a maximum solar intensity of 84.84 deg. when the earth is in aphelion, the temperature for each day during the year being calculated in accordance with the varying distance between the sun and the earth. Observations made at different seasons, for the purpose of testing the correctness of the computed temperatures, have proved quite satisfactory. The reader is referred to an article on this subject in "Nature," vol. v., pp. 46–48.† It is scarcely necessary to point out that our table, together with the tabulated statement, showing to what extent solar temperature is modified by zenith distance (published in "Engineering," vol. x., page 240),‡ are indispensable to the meteorologist. Evidently, an observation of solar temperature affords no means of judging of the state of the atmosphere, unless the effect of zenith distance, and of the position of the earth in the orbit at the time of making the observations, are known. By consulting the tables, an observer can detect at a glance whether the temperature produced indicates a clear sky. It also enables him to determine the exact degree of atmospheric obstruction.

THE Mont Cenis Tunnel is 12,236 metres long—nearly eight miles—26 ft. 8 in. wide, and 20 ft. high. About 6,000 men were employed for nine years in its construction, and its cost was $13,000,000.

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* See MAGAZINE, Vol. III., p. 566.

† See MAGAZINE, Vol. VI., p. 92.

‡ See MAGAZINE, Vol. III., p. 566.

EXPERIMENTS ON THE DEFLECTION OF CONTINUOUS BEAMS, SUPPORTED AT EQUIDISTANT POINTS.*

By JAMES B. FRANCIS, C. E.

In the case in the deflection of beams, "fixed at each end and loaded in the middle," there is a discrepancy in the leading authorities.

According to Barlow (Report on the Present State of our Knowledge respecting the Strength of Materials, made at the third meeting of the British Association for the Advancement of Science, held at Cambridge in 1833), the deflection is two-thirds of that in the case, "supported at each end and loaded in the middle." According to Navier (Resume des Leçons donnees a l'ecole des Ponts et Chaussees, sur l'application de la Mecanique, etc. 2d edition, Paris, 1833), it is one-quarter or three-eighths only, of the deflection according to Barlow.

Not feeling competent to decide which, if either, of these eminent authorities was correct, and having occasion to apply it in practice, I made the following experiments:

A frame was erected, giving four bearings in the same horizontal plane, 4 ft. apart, making three equal spans, each bearing being furnished with a knife edge on which the beam was supported. Immediately over the bearings, and secured to the same frame, was fixed a straight edge, from which the deflections were measured.

Experiment 1.—A bar of "common English refined" iron, marked "J crown K, best," 12 ft. $2\frac{3}{4}$ in. long, mean width 1.535 in., mean depth 0.367 in., was laid on the four bearings, and loaded at the centre of each span, so as to make the deflections the same, the weight at the middle span being 82.84 lbs., and at each of the end spans 52.00 lbs. The deflections with these weights were as follows:

At the centre of the middle span, 0.281 in.; at the centre of the end spans, 0.275 and 0.284 in.; mean, 0.280 in.

The deflections of the three spans being, as nearly as practicable, the same, the middle span is in the condition of a beam "fixed at both ends and loaded in the middle," each of the end spans "being fixed at one end and supported at the other." A piece 3 ft. $11\frac{1}{2}$ in. long was then cut off from each end of the bar, leaving a bar 4 ft. $4\frac{3}{4}$ in. long, which was replaced in its former position and loaded with the same weight (82.84 lbs.) as before, when its deflection was found to be 1.059 in., or 3.77 times the deflection when "fixed at both ends and loaded in the middle."

Experiment 2.—A bar of iron of the same quality and length as in Experiment 1. nearly square, its mean width being 0.553 in., and mean depth 0.549 in., was laid on the same bearings, and loaded with the same weights, the deflections being as follows:

At the centre of the middle span, 0.242 in.; at the centre of the end spans, 0.238 and 0. 244 in.; mean, 0.241 in.

The bar was then reduced in length as in Experiment 1, leaving 4 ft. $3\frac{3}{4}$ in., which was replaced in its former position and loaded with the same weight (82.84 lbs.) as before, when its deflection was found to be 0.983 in., or 4.06 times the deflection, "when fixed at both ends and loaded in the middle."

The result of both experiments agreed substantially with Navier, who finds the deflection in the case of a beam "fixed at one end, supported at the other, and loaded in the middle," to be $\frac{1}{\sqrt{5}} = 0.447$ of the deflection in the case, "supported at each end and loaded in the middle." In the foregoing experiments, the end spans correspond to this case, and the observed deflections with a weight of 52 lbs., were 0.419 and 0.391 respectively, of the deflections in the case, "supported at the end and loaded in the middle," differing somewhat, but not very widely, from the proportion given by Navier.

* A paper read before the American Society of Civil Engineers.

Between the Bevier coal mines and those of Shortridge & Co., the Union Pacific Railroad Company are now sinking a shaft, to supply the Omaha end of their road with fuel. This enterprise is another blow at the coal monopoly that has heretofore existed upon the Hannibal and St. Joe Railroad, and will aid in the good work of helping to furnish a cheap fuel to the roads north and west.

ULTIMATE AND WORKING STRAINS.

From "The American Railway Times."

The rate of the breaking to the working strain has been variously fixed, for the several materials, by different engineers. A beam may be loaded with a greater weight applied as a permanent or dead load, than could be safe as a moving or rolling weight. A load may be brought upon any material in an easy and gradual manner so as not to damage it, while the same load could not be suddenly and violently applied without injury. The margin for safety should be greater with a material liable to certain hidden defects, than with one which is not so. It should be greater for any member of a structure where it is subjected to several different kinds of strain, than when it is subjected only to a single form of strain. The rule in structures having so important an office to perform as railway bridges, should in all cases be *absolute safety under all conditions.*

In the Louisville bridge Mr. Fink has adopted 7 as the factor of safety for the cast-iron chords under an extreme load, and from 5 to 6 for the posts and braces. The wrought iron work in the same bridge is strained from 7,000 to 12,000 lbs. per in. by the maximum load, according to its position in the structure. In the Quincy bridge the lower chords and ties are strained from one-seventh to one-eighth of the ultimate strength by the greatest load. In the Niagara bridge the cables have an ultimate strength of five times the utmost probable load. In the fine wrought-iron elliptical arch upon the Pennsylvania Railroad at Thirtieth street, Philadelphia, Mr. Wilson has employed a factor of safety of 6 throughout. In the Canestota bridge, a wrought iron lattice upon the New York Central road, Mr. Hilton has adopted 5 tons per in. for the working strain upon the *net* section of the lower chords, 4 tons for the compression upon the *gross* section of the top chords, 5 tons upon the *tension* bars of the lattice, and 3 tons upon the *compression* bars. In the bridge across the Ohio river at Steubenville, of which the channel span is 320 ft., a rolling load of 3,000 lbs. per ft. produces 10,000 lbs. of tension on the lower chords, and the same amount of compression upon the top chords, the latter being of cast iron. The factor of safety for the braces is one-eighth.

In the bridge across the Connecticut at Warehouse Point, on the Hartford and New Haven Railroad, the maximum tensile strain is 5 tons, the compression on the top chords 4 tons, and on the posts 3 tons, all the members being of wrought iron. The channel span is 177 ft., and is proportioned for a load of 2½ tons per ft., including the weight of the bridge.

In the Kansas City bridge across the Missouri, the central tie roads and the truss rods of the floor beams were proportioned for 10,000 lbs. per in.; the end ties and lower chords 12,000 lbs.; the compression on the top chords, which are of wood, 800 lbs. per in.; and for the wooden braces a factor of 7 was adopted.

In the valuable pamphlet by Mr. C. Shaler Smith, comparing the several principal bridge trusses now in use, he observes: "In determining the proportion of safe to breaking strain, respect should be had to the frequency with which the parts are subjected to stress by the moving load, as this will manifestly influence their powers of endurance. The primary system of a truss, that is, the system which upholds the entire structure, when weighted with its maximum load from end to end, such as the chords of a Murphy, or Triangular, or the main and secondary tension bars of a Fink bridge, may be safely subjected to a heavier strain than the tertiary and panel systems of the Fink, or the panel systems of the other trusses, the latter of which are fully strained by the engine leading every train; while to strain the primary systems to the utmost limit allowed would require a train made wholly of engines." In making comparisons of several forms of truss, Mr. Smith accordingly uses 10,000 lbs., per in. for the quarternary system of the Fink bridge, and for the middle panels of the other trusses, as the working load for the wrought-iron tension bars. For the tertiary system of the Fink, and the first four panels of the other trusses, 11,000 lbs. is adopted, and for the primary and secondary systems of the Fink, and the chords of the Murphy and Triangular, 12,000 lbs. For the cast-iron parts, for chords and large posts when, the metal is an inch and over in thickness,

and the length not over fifteen diameters, the factor is taken at one-fifth; with metal not less than five-eighths, and length not over twenty-five diameters, one-seventh; and with metal less than five-eighths, and length over twenty-five diameters, from one-tenth to one-fortieth.

Mr. Stony (Theory of Strains, Vol. II. p. 387) gives the following figures: The working tension in the lower flanges (chords) of the Conway Tubular Bridge, span 400 ft., from the permanent weight of the structure, is 4.385 tons per sq. in. of gross section; the compression in the upper flanges is 3.063 tons per in. The working tension, with one ton per foot of rolling load, is 6.85 tons, and the compression 5.03 tons. In obtaining the above figures, the vertical webs are not taken into account, and the rivet holes are not deducted from the flanges. In the Newark Dike Bridge, 240½ ft. span, the top chords and braces of cast iron, under a rolling load of a ton per foot, are strained to five tons per inch, and the lower chords and ties of wrought iron are strained to the same amount. In the Boyne Viaduct, a wrought-iron lattice, 264 ft. span, the working tensile strain for the net area of the lower chords, under a rolling load of 1 ton per ft., is 5 tons per in., and the compression on top chords 4.5 tons. In the Charing Cross Bridge, a lattice of 154 ft. span, with four lines of railway, the working tensile strain at 1¼ tons per lineal ft. on each of the lines, is 5 tons per in. and the compressive strain 4 tons.

In the Crumlin Viaduct, a Warren girder, 148 ft. span, the maximum tensile strain in the diagonals from the bridge and load is 6.65 tons per sq. in. of the net section; the tension on the lower chords from the same strain is 5.75 tons per sq. in. of net section; and the maximum compression on the top chords is 4.31 tons per in. of *gross* section.

Mr. Unwin (Iron Bridges and Roofs) gives the following strains in several recent wrought-iron bridges, the tension being for the net section, and the compression for the gross section of the metal:

Name of Bridge.	Tension. Tons per in.	Compression. Tons per in.
Passau, lattice	5½ to 6	4½ to 5½
Penrith, tubular girder	4¾	4¼
Place de l'Europe, lattice	4½	3¾
Lough Ken, bowstring	4	3¾
Isere, lattice	4½	3½

The following figures show the working strains upon several of the larger suspension bridges:

Name of Bridge.	Working strain in tons per inch.			
	Length of cord of catenary in ft.	From the bridge.	From bridge and load.	Factor of safety.
Menai	580	4.21	8 00	3.9
Hammersmith	422½	5.38	9.36	3.3
Pesth	666	5 01	8 11	3.9
Chelsea	348	4 36	8 07	3.9
Clifton	702½	2.90	5 03	6.2
Niagara	821	6.70	8.40	5 0

The load from which column 3 is computed is assumed at 80 lbs. per square foot of the floor, except in the case of the Niagara bridge, where it is reckoned at 250 tons in all. The factors in the last column are obtained by assuming the ultimate tensile strength of the chain links, which are made of very superior iron, at 70,000 lbs. per inch; and for the Niagara bridge, which has wire cables, at 100,000 lbs.

Mr. Humber, in his large work on bridges, furnishes the following concerning several cast-iron arches:

Name of Bridge.	Length of span.	Versed sine of arch.	Strain per sq. in. tons.	Depth of rib.
	′ ″	′ ″		′ ″
Austerlitz	106 0	10 7	1.78	4 4
Carrousal	154 2	16 1	1.46	1 10
St. Denis	102 5	11 4	1.37	2 10
Nevers	137 9	15 0	1.90	3 9
Rhone	197 10	16 5	2 37	5 9
Westminster	120 0	20 0	3.00	....

In determining the factor of safety, regard should be had to the proportion that exists between the dead and the live load. A rolling load has been assumed by engineers (and for practical purposes the assumption is probably correct) as equivalent to a dead load of double the amount. In determining the factor of safety, therefore, we may reduce the whole load to an equivalent dead weight, which will be equal to twice the actual live load added to the actual dead load;

or we may, as Mr. Rankine suggests, multiply each part of the load by its proper factor of safety, and add together the products, the sum being the breaking load to which the structure is to be adapted. Thus, regarding a ton of live load as equivalent to two tons of dead load, and adopting a factor of one-sixth for live and one-third for dead weights, if we have 200,000 lbs. of dead load, and 100,000 lbs. of live load, the equivalent dead weight is 400,000; and the factor being 3, the breaking weight would be 1,200,000 lbs.; or we may multiply the 300,000 by 3, and the 100,000 by 6, giving the same result. If the dead load was 200,000, and the live load 100,000, we should find the breaking weight to be 1,500,000 lbs. in place of the 1,200,000 above.

Mr. Fairbairn subjected a wrought-iron plate girder, of 20 feet span and 16 in. deep, to repeated deflections by means of a loaded lever, with the following results: A load of 2.96 tons applied at the centre at the rate of about 8 changes a minute for 596,790 times producing a deflection of 0.17 in., and straining the net section of the bottom flange 5.92 tons per. in., produced no apparent change. Increasing the load to 3.5 tons, 403,210 additional deflections of 0.23 in., straining the bottom flange to 7 tons per in. produced no visible change. Increasing the load to 4.68 tons, 5,175 additional deflections, depressing the girder 0.35 in., and straining the lower flange 9.36 tons per in., produced a permanent set of 0.05 in., and tore the lower flange apart near the middle. The girder being repaired, a load of 2.96 tons applied 3,124,000 times produced no permanent set. A load of 4 tons, applied 313,000 times, produced a deflection of 0.20 in., straining the lower flange to 8 tons per in., and broke the girder close to the splice over the former fracture. Thus a strain of 5.92 tons per inch of the lower flange section, the breaking weight being 20 tons per inch, would seem to be a safe load.

Mr. Fairbairn found also that small cast-iron posts 6 ft. long, and an inch in diameter, bore a constant load of half the breaking weight for three years without changing; while with three-fourths of the breaking load the deflection was slightly increasing at the end of the same time. He also subjected model bars of cast iron 4 ft. 6 in. long between the supports, and an inch square, to a cross strain of from one half to over three-fourths of the breaking weight. These loads were borne with a slightly increasing deflection for over five years. The greater part of the deflection occurred during the first year, after which it remained very nearly constant. In the report of the commissioners upon the application of iron to railway structures, experiments are referred to in which cast-iron bars, supported at the ends, were subjected to successive deflections—in some cases as many as 100,000,—by means of a cam, at the rate of four per minute. When the depressions were one-third of the ultimate deflection, the bars were not apparently weakened. When, however, the depressions were one-half of the ultimate deflection, the bars were broken with less than 900 flexures. A load equal to half the breaking weight, moved backwards and forwards from one end to the other of a cast-iron bar, produced no apparent weakness by 96,000 transits.

For cast-iron bridges, the British Board of Trade has directed that the breaking weight should not be less than three times the permanent load from the bridge itself, added to six times the greatest rolling load. The general opinion of engineers, however, is, that the breaking weight should be four times the total load for good-sized castings, supporting a dead weight, six times for large castings subjected to changes of load and vibrations, as in railway bridges, and eight times for small castings and for work subjected to particularly violent and sudden shocks.

"The resisting powers of beams," says Mr. Fairbairn, "of whatever material they may be composed, are like the muscles of the animal frame when strained beyond their reasonable powers of resistance. They may for a time endure the load, and probably a few repetitions of it; but the result generally is either the rupture of the several parts, or the total suspension of those qualities by which its elasticity and powers of restoration are maintained. It therefore follows that every description of material, when subjected to a transverse strain, should never be urged to greater endurance than may be required to straighten the fibres, or arrange the molecules of its crystalline structure. Any strain beyond that point is attended with risk; and in every case where the beam is subject to alternate change oi vibration, to dead weight, and the force of impact, it is safer to mul-

tiply the load by 4 than by 3, as the ultimate strength of the beam. In girders for railway bridges the multiplier should never be less than 5, and in most cases even 6 is preferable, owing to the great weight and high velocities with which trains pass over a continuous line of rail, involving equally severe tests of impactive force on every structure, whether beams or bridges, that have to support the immense weight of railway traffic, varying in speed from 25 to 50 miles an hour."

THE WESTINGHOUSE AIR BRAKE.

From "The Engineer."

The Westinghouse brake—so called because the inventor is a Mr. Westinghouse, of Pittsburgh, U. S.—differs from all the other air brakes which have been brought before the world, in two principal features. The first is the system of obtaining compressed air; the second is the kind of coupling joint used to unite the pipes establishing communication throughout the train. In all the air brakes hitherto tried the compression of the air has been effected by a pump or pumps, worked either from the wheels of the tender or of the guard's van. Generally speaking, the *modus operandi* is like this:—One, two, or three air pumps are fixed in a case within the guard's van. These are actuated by a crank shaft driven by a strap from one of the van axles. Any conceivable form of clutch may be used to suspend or establish the motion of the crank shaft and of the pumps at pleasure, and this clutch or its equivalent is under the control of the guard. The objections to this arrangement are so numerous that, although the scheme has often been tested, it has never obtained adoption by railway men. In the first place, if the guard does not put the apparatus in action soon enough there is no pressure of air ready when wanted to actuate the brakes, and the pressure cannot be obtained until the whole train has run far enough to give the requisite number of strokes of the pump. We can call to mind a case in which such a brake was tested, and no less than seven seconds elapsed before sufficient pressure was obtained to put the brake on. Now seeing that a train moving at 50 miles an hour passes over 73 ft. a second, this would represent a distance of no less than 511 ft. But with a good continuous brake, applied *at once*, a heavy train might be stopped altogether in little more than the distance thus wasted in merely getting the brakes to begin to act in the case named. Another objection is, that the whole of the pumping must be done, in any case, in a very few seconds, and the machinery is thus run at a very high speed over which no one has any control, the velocity of the air pump crank shaft being normal to that of the train. Again, if brakes are fitted to the van, it is certain that, from causes well understood, the maximum pressure will be reached in the van cylinder before it is reached at the end of a long train. The van wheels will, therefore, be skidded, and the augmentation of pressure will cease before the brakes are applied under the other vehicles with full force. Mr. Westinghouse gets rid of all these objections *en bloc* by using an independent donkey engine to keep a reservoir full of compressed air at all times. This reservoir holds enough air to put all the brakes on a long train on at once. As there is nothing like a fact to prove an argument, we may state here that a train of 33 American cars, extending in length over a quarter of a mile, and weighing in all 550 tons, was run down an incline of 1 in 95 at a speed of 35 miles an hour. This speed attained, the brake was put full on, and the train was stopped within a distance of 700 ft. The first argument that will be raised against the Westinghouse system of compressing air, is that a donkey pump cannot be made witout a flywheel and appurtenances which will do the required work with certainty. We confess that on this point we were a little doubtful, and we did not rest satisfied until we had tried for ourselves how much reliance was to be placed on Mr. Westinghouse's pump. On Monday, the 13th inst., we travelled from Euston-square to St. Albans and back, on a locomotive fitted up under Mr. Westinghouse's patents. We found the action of the pump to be all that could be desired. There is, practically speaking, no speed so slow that it will not work with regularity; and nothing was more interesting than to watch the action of the pump from the foot-

plate while the train was running at a high speed. Steam was nearly all but shut off from the donkey. Yet every five seconds or so the reversal of the valve gear could be seen to take place; and so the donkey pursued the even tenor of its way, maintaining a steady pressure of about 70 lbs. in the reservoir under the foot-plate. Mr. Westinghouse has applied this pump as a boiler feeder, and one with a pump 4 in. diameter and 14 in. stroke runs steadily at a speed as low as *one* stroke only per minute. Once more, bringing facts to back up arguments, we may state that there are at this moment over twelve hundred Westinghouse pumps at work in the United States, and that their construction, and that of the other portions of the brake, afford full employment to a large engineering establishment at Pittsburgh. This pump, then, is no toy. It is as much an article of commercial manufacture and sale as a reaping machine or a portable engine; and it is quite as reliable in its action, and as certain to give no trouble as either one or the other.

We have stated that the second feature of importance in this brake is the system by which the pipes are joined when a train is being made up. We have not the slightest hesitation in saying that the joint used will well repay the closest examination. It is simply an exquisite adaptation of mechanical means to a required end with the least possible complication of apparatus. The joint is as perfect, perhaps, as it is possible to make a joint, every obstructive contingency having been contemplated and disposed of. The joints practically take care of themselves. There are no screws, cocks, or complex couplings. We have only, to put the matter in plain terms, to stick one end of a pipe into another end of another pipe, to give the joint a half twist, and the joint is made good. The little india-rubber band forced out by the pressure within is as neat an application of means to an end as is the leather collar by which Bramah made the hydraulic press a success. No joint possessing anything like the advantages of this joint has ever been applied to a kindred purpose. Both pipes we have found, by experience can be coupled in 10 sec. It may perhaps be urged that the gun-metal couplings may get knocked about and injured. This is improbable; but, to guard against the chance of injury from the blow of a swinging drawbar, a heavy india-rubber band is slipped over the clamps; and besides, a rimer is supplied with each set of brakes. This rimer is made to gauge, and, should it be found that the joints do not go together freely, the carriage examiner, who is supposed to carry this rimer, applies it to the defective coupling, and, by a single turn, removes any grit or imperfection which may interfere with the action of the coupling. In practice this rimer is rarely, if ever, found necessary. It constitutes the embodiment of a measure of precaution, however, useful in its way.

A great objection to many systems of continuous brakes lies in the fact that the action of the springs of the carriage is completely arrested when the brake is put hard on, the carriage being then made one with the wheels. Mr. Westinghouse gets over this difficulty in two ways. In the first place, the brake blocks are hung on the flap plan from the framework, by which about 2½ cwt. are saved in the weight of the apparatus as compared with the slide brake; while the brake blocks are hung by joints at the centre, instead of being bolted rigidly to the flap bars or hangers. A moment's thought will prove that, under these conditions, a certain amount of motion is still left to the axle-boxes; the wheels can play up and down under the carriages, the joint in the brake block permitting the motion of the axle-boxes in the iron plates. It may be argued that the play must be limited, because the axle must move through a curve the radius of which is equal to the distance between the centre of the wheel and the centre of the pin on which the brake block pivots; but this would only be true if the brake were rigidly applied, as by a screw. The wheel really moves nearly vertically in the horn-plates, the brake being pressed home by the elastic action of the air in the brake cylinder, following all its motions faithfully. This in itself is a most valuable point, which we have never seen applied in practice before. The brakes do not drive the axle-boxes hard against the horn-plates, because the axle boxes are united by a light tie rod which holds them together in a way too obvious to need explanation. In order to secure the equable action of both brake blocks, an ingenious equalizing bar is introduced, the action of which is, on the one hand, so simple as hardly to require an engraving, and, on the other, not so obvious that it is easy to explain it without one; suffice it to say that the piston rod of the brake cylinder, instead

of being coupled direct to the single arm of a rocking shaft, is coupled to the middle of a short transverse bar, the ends of which are each jointed to two levers, one on each half of a double rocking shaft, one half of which acts on one brake while the other half acts on the other at the opposite end of the carriage. The action is precisely that of a whipple-tree, or, to put it in more mechanical phraseology, that of the well-known "jack-in-the-box" gear.

An objection has been raised that the blocks, from rapid wear, will require constant readjustment. Here Mr. Westinghouse introduces us to a novelty in the shape of cast-iron brake blocks. These have been in use for years in the States, and there does not appear to be any valid objection to their use here. The idea that "they will not do" comes out on examination to be only an idea. They will not wear flat places in the wheels; on the contrary, they grind flat places out of them; and extended experience with their action on steel tires in America goes to show that they are less injurious to the wheels than wood blocks, which catch and hold sand. On the whole, the cast iron blocks appear to have a little less grip than wood in dry weather, but in wet weather the coefficient of adhesion is much greater than that of wood, so that the average efficiency of a cast-iron block the year through is greater than that of a wood block. As regards heating, careful experiment has proved that the maximum temperature attained by cast iron blocks in summer is but 132 deg. They have been in use for three months on the Caledonian Railway, and have given perfect satisfaction to Mr. Connor, who, we may add, was the first to give the Westinghouse brake a trial in this country.

As an example of the adaptability of the Westinghouse brake to local traffic trains, we may state that it has been for two years in constant use on a local train on the Pennsylvania Railroad. This train runs 14 miles into the country, stopping at 23 Stations. The train makes 8 trips a day during the week, and 2 trips, or 46 stoppages, on Sunday. We have nothing to parallel this, except perhaps, on the Metropolitan Railway.

We have mentioned elsewhere that a system of signalling is combined with the action of the brake, and the description of the apparatus must be read carefully to make the action of the signalling apparatus intelligible. It is extremely simple, and has, so to speak, grown out of the brake without any special culture. We tested its merits, however, on Monday, the 13th instant. Almost any signal can be heard on a locomotive footplate when the weather is fine and the line open, and there was no difficulty in this case; but to test it still further, we stood away as far as possible on the large footplate of the heavy engine to which the apparatus is fitted on the London and North-Western Railway, and when going at full speed through Primrose Hill tunnel we heard the whistle with the greatest ease, although we did not know previously that a signal was to be sent us from the guard's van just then. We believe that this signal apparatus deserves attention and elaboration.

We should not have given the subject so much prominence, but that we have assured ourselves, both by personal examination and inquiry, that Mr. Westinghouse has practically solved on the largest possible scale, one of the most perplexing problems that ever beset the modern railway engineer.

ARMOR FASTENINGS FOR IRON-CLAD SHIPS.

From "The Annual of the Royal School of Naval Architecture and Marine Engineering."

The question of armor fastenings having, during the present year (1871), been again revived, and grave charges brought against the Admiralty and others who persist in the adoption of the common or minus-threaded bolts, we propose to lay before our readers a few facts in connection with this subject, showing why the Admiralty continues the use of this form of bolt for armor-clad ships in preference to the plus-threaded, and we are the more anxious to do so on account of the vague notions which certain writers in our public journals seem to have with reference to this matter.

Armor fastenings have already provoked a great deal of discussion, owing to the different opinions held by those who have taken any prominent part in the construction of our iron-clad ships and land fortifications. But when two great departments

of the State agree to differ, and each deliberately decides to adopt its own peculiar views, and that, too, after a costly series of experiments has been made to settle disputed points, it is no marvel that the public should express their dissatisfaction at this apparently anomalous procedure; and the case becomes all the more aggravated when the merits of the plus-threaded system are paraded in the newspapers with a plausible claim to superiority, and the minus-threaded bolt is represented as being *minus* of every good quality.

We read an article in one of our daily newspapers a short time ago, censuring the Admiralty in no measured terms for what was termed its persistent folly in not abandoning its system of armor fastenings and adopting the plus-threads. Now we must beg to differ altogether from the advocates of such views, for, in our opinion, the folly would be in acting upon their suggestions. This we hope presently to show would be the case both as concerns economy and efficiency. Does it follow, because the War Department has thought proper to sanction the use of these particular bolts for land fortifications, that therefore the Admiralty must do the same for armor-clad ships? It may just as well be argued that animals which have been formed by the Creator to dwell on dry land, could live equally well in the sea if they would only try, as to suppose that the same description of work can be made to answer alike in both cases.

Armor-clad ships, we need scarcely say, have to carry and fight their guns, and must be constructed so as to be impervious to water as well as impregnable to shot, an achievement not very easily accomplished. The difficulty, for instance, of keeping these ponderous ships water-tight will be the more apparent if we consider how they are tossed upon the billows, and plunged into the hollow of the waves. The wonder is that they keep so free from leakage as they do, but this can only be effected by good, sound work, which we are glad to say the Admiralty always insists on. We may mention, as an instance of the great force with which water impinges against the bows of a ship, that in one of our earliest iron-clads, during her trial at sea, the manger scuppers, of lead $\frac{3}{8}$ in. thick, collapsed, owing to the water forcing its way through the joint made with the scupper and wood fillings. The water pressing or impinging against the sides of our ships with such force renders it necessary, therefore, that the greatest care should be taken with the fastenings, and bolt-holes have to be caulked round the inside between the joints of the skin and wood backing, and a hempen grummet placed under the washer to prevent leakage. Yet, notwithstanding these precautions, the water sometimes forces its way through.

Before proceeding with the more technical part of our subject, let us define the terms we have applied to these bolts. Suppose, then, a screw-bolt to be made in the ordinary manner, the threads being cut on the points, as is usual for a common bolt, the diameter of the bolt, measured at the smallest part of the screw, will of course be less than the diameter of the shank. This, then, is what is meant by the term *minus* threads. Now, if we put this same bolt into the lathe and turn down its shank between the head and screw point until it is reduced in diameter to the smallest section of the screw point, or a trifle below it, we shall have the *plus* threads. In other words, the screw thread will be in relief upon the shank, and consequently the point will be larger than the shank by the depth of the screw thread.

There is nothing novel in this description of screw thread, for it has been used for certain works from time immemorial; but the application of the principle to armor-bolts is, we believe, modern, and is patented by Major Palliser, who, some years ago, when armor-plating was in its infancy, witnessed, in common with others, a series of experiments at Shoeburyness with the armor-plated targets, representing both the sides of our iron-clad ships and our land fortifications. Seeing how destructive the firing at these targets proved to the armor-bolts, he immediately turned his attention to remedying this defect, which he endeavored to do by changing the form of the bolts then in use, making them with plus in lieu of minus threads, and at the same time using a more costly and ductile quality of iron, with a view to resist impulsive strains. Others attempted to attain the same result by the introduction of elastic washers placed under the nuts, so as to deaden vibration and allow the bolt to yield at the moment of impact by shot. Various contrivances for these washers were resorted to, both with regard to the form and also the material, and at length the elastic cup washer was proposed and adopted for

armor-clad ships, while the plus-threaded bolts were adopted for land fortifications. Both systems, it will be observed, aim at relieving the bolts from strains of enormous magnitude suddenly applied. In the one case the object is attained by the application of an elastic substance, placed, as we have said, under the nuts, and in the other by the stretching of the bolts themselves.

The elastic cup washer is fully described and illustrated in "Shipbuilding in Iron and Steel," by Mr. E. J. Reed, C. B. A brief description of it here may, however, be of advantage. It consists of three articles—viz., a wrought-iron cup, having a flat surface to fit against the skin plating, an india-rubber washer which is placed inside the cup, and a covering plate of common washer. These have each a hole through their centres of the size to suit the diameter of the bolt to which they are to be applied. They are then threaded on to the point of the bolt in the order stated, the plate-washer or covering plate forming a base against which the face of the nut fits when screwed on. The proportions of these articles must depend upon the size of bolt and thickness of armor plate. By this arrangement a kind of buffer is formed; but as india-rubber while being very elastic is practically an incompressible substance, care must be taken to allow sufficient room around the edge of the covering plate, so that when the bolt is overstrained by concussion, the india-rubber may be allowed to exude. The space around the edge of the plate referred to must be regulated by the texture of the india-rubber, and this last-mentioned quality must depend upon the size of the armor bolt. The form of these washers is hexagonal. This is for the purpose of preventing the india-rubber from twisting when a heavy strain is put upon it by screwing up the nut. They may be of cylindrical shape, provided the covering plate can be so fitted as to prevent its rotating while the nuts are being screwed up. The cup is intended to be a repository of latent elasticity, which will allow the bolts to yield at the moment of impact by shot at every round until the whole of the india-rubber has been squeezed out of the cups, just on the same principle as the stretching bolt which stretches until it breaks. So far, then, as yielding is concerned, the two systems may be said to be identical.

It must further be remarked with respect to the plus-threaded bolts, that Major Palliser, subsequently to the time we have referred to, added two other features to his system, viz., extremely fine threads, and a new method of forming the conical heads, concerning which he laid down a rule that they should not be made by *upsetting* the iron, as is commonly done by smiths when employed on this description of work; so to carry out this idea, the bolt staves have to be provided large enough for the required diameter of the conical head. The iron is then "swaged" down from this larger diameter to that required for the shank of the bolt, the head being, of course, formed by the same operation.

The bolts now being used by the War Department for land fortifications differ in form from those we have just described. For instance, nuts take the place of heads, and the bolts closely resemble those used by civil engineers and others for the tie-bolts of bridges, etc. The mode of manipulation is, however, very different in the two cases. Those for land fortifications are made from bolt stave of the diameter of the largest part of the screw threads, the shanks between the screw threads being afterwards turned down to the smaller diameter; while the tie-bolts referred to are made by simply upsetting the iron in order to obtain the increased diameter for the raised or plus thread. This is a matter of great importance from an economical point of view, and we will therefore give a few particulars illustrative of the precautions taken to insure the desired quality in the bolts made for the War Department.

From each length of bolt stave—say from 15 to 18 ft.—a test piece 2 ft. long is cut and prepared. It is fixed in a vertical position under a steam hammer by an apparatus specially arranged for the purpose, and then drawn asunder lengthwise by repeated blows. There must be a certain percentage of reduction in the breaking section as compared with the original section of the test piece, in order that the stave from which it was cut may be accepted. Should this percentage not be obtained, the whole stave is rejected. Our readers will probably think this an extravagant and costly precaution, especially when compared with the Admiralty test of one bolt out of every hundred.

The latter test is also percussive, but is made by means of an article termed a "tub" (about 1 ton in weight), let fall through a space of 30 ft., the test bolt being

so placed that the fall of the tub shall bring upon it strains similar to those caused in the fastenings by the impact of shot upon the armor plates on a ship's side. Of course, with the War Department's system of fastenings, great ductility is, as we have said, essential to the success of the bolts, and the elaborate tests described above are indispensable. But a quality of iron which would certainly fail to satisfy the War Department's requirements, and would break under trial because of its want of ductility, might with elastic cup washers answer every purpose. The difference in the cost of the iron would be considerable, as some of our readers will understand when we state that the quality now being used by the War Department, and manufactured by Sir John Brown & Co., costs £21 per ton.

The nuts and washers for land fortifications are also of a novel pattern. They are made on the ball and socket principle, and are termed spherical nuts and coiled washers. The socket for the nut which answers for the head of the bolt, is made in the armor plate itself by countersinking the plate to fit the spherical nut.

The washers at the points of the bolts are made up of two parts as follows: A socket to receive the nut (circular in form) is first made out of coiled bar iron welded, of the required thickness. On the outside of this a screw thread is cut for the purpose of receiving a jacket or coil of bar iron, which is first put into shape by being bent hot to the form required, and when cold a screw thread is cut on the inside to coincide with that on the external part of the socket. This coil is not welded. The two are then screwed together, forming one washer, the coil on the outside acting as a supporter in order to prevent the socket from bursting at the moment of impact by shot, and at the same time giving elasticity to the nut. The nuts being thus made from coiled iron are expected to expand when concussion takes place, and so allow the nut to yield to the strain. It will therefore be observed that the materials of which these bolts and nuts are made must be of the very best description and of special manufacture. The washer is patented by by Lieutenant English, R. E.

Shipbuilders will at once see from our description of these bolts that they are not at all adapted for iron-clad ships, in their original form, and that in order to render them suitable their shape must be changed, so that externally they may be of the same form as the minus-threaded bolts, by coating them with some metallic or other substance—that is to say, instead of their points being larger in diameter than their shanks, the order must be reversed, and the points must be the smaller. This is absolutely necessary to insure sound watertight work, and in some of the earlier Palliser bolts the recessed part of the shank was filled up with an alloy of antimony and lead for this purpose, but the plan was afterwards abandoned. The additional expense (we were told at the time) for this extra work so increased the cost as to make them equal in value to their weight in silver. But this was, no doubt, an exaggerated statement.

We shall not stay here to discuss the merits of this combination of metals, further than to say that we should not like to answer for the consequences which would be likely to ensue when these metals are brought into contact with sea-water.

But let us now suppose that this plan can be carried out by the introduction of some metallic or other substance, and that the bolts, having been driven tightly through their holes, are water-tight. The ship goes into action. What follows? According to the theory of the patentee, the first blow the armor plating receives, the bolts in the vicinity of the shot-hole, or indent, as the case may be, are to stretch, and as a necessary consequence there will also be a corresponding reduction in the diameter of the bolts so acted upon. These bolts of course are at once rendered slack in their holes, when leakage must ensue if the damage is in the neighborhood of the water-line, and this at a time, above all others, when water-tightness should be preserved, and the guns, and not the pumps, well manned.

We may also mention another contingency which has to be studied, should this plan be carried out, and that is the probability of the nuts jarring off at the moment of impact by shot, owing to their not bearing evenly against the skin plating, on account of the difficulty of boring the holes exactly at right angles to the side of the ship. We know that the slightest deviation in this respect will cause a transverse strain to be brought upon them simultaneously with the tension, and the effect of this will be to fracture the bolt at the thread next to

the skin plating, and so jar off the nuts. We do not say that this defect could not be obviated by using tapering washers; but even then there would be a degree of uncertainty about it, as the workmen themselves may be deceived in this manipulation, and the same evil would exist in the common bolts, were it not for the elastic cup washer, which acts as a regulator in this respect, for no sooner is a slight strain put upon the india-rubber which is confined within the cup, than a uniform bearing under the nuts is virtually obtained by the accommodating nature of this material.

The spherical nuts already mentioned were introduced, no doubt, partly to obviate the same evil; but then it must be borne in mind that bolts used for land fortifications are all loose in their holes, which allows the nuts to accommodate themselves when a sudden tensile strain is brought upon them, and it is not too much to say that the success which has attended the trial of these bolts is in some measure due to this fact.

The benefit derived from the india-rubber has been fully verified by the experiments at Shoeburyness, and although the late trial with the 14-inch plated target was not so successful as could have been desired, this ought not to detract from the merits of former trials, but, on the contrary, should form a ground for inquiring why the bolts for thick plates cannot be made to stand as well as those used for thinner ones. We are glad to find that this view of the case has been entertained by the Admiralty, and the partial failure referred to will no doubt be rectified in the ships themselves.

New systems of work, or reconstructions, as they may be termed, are seldom or ever developed all at once. Experiment after experiment has sometimes to be made before certain vital points can be satisfactorily determined. This is especially the case with regard to armor plating and fastenings. No sooner have the requirements in one case been fairly met, than the arrangements have to be altered to suit another where the parts are of larger dimensions and of different construction, owing to the guns gradually growing in weight and calibre. Consequently the professional officers who have to arrange the details of construction are continually having forced upon them a readjustment of the fastenings, involving the employment of bolts of larger diameter, stronger cups, and an increase in the thickness of india-rubber. These particulars have all to be decided, and this cannot be done correctly in the absence of experiments, owing to the amount of buckling these extra thick plates will undergo at the moment of impact by shot. This was evidently the case with the last experimental ship target tried at Shoeburyness. The firing at this target with the 25-ton gun was so terrific in its results, that the wrought-iron cups which contained the india-rubber were found to be too weak to withstand the violent concussion and sudden distortions of these extraordinarily thick plates, consequently the cups burst sideways, allowing the india-rubber to escape, thus bringing at once iron into contact with iron, and fracturing the bolts. But it is worthy of remark that all the bolts withstood the first round, although the cups burst.

If is impossible to anticipate the effects of the discharge of one of these heavy pieces of ordnance against an armor-plated target, and therefore it is not fair to expect that all the necessary details can be successfully arranged before some idea has been formed as to the requirements of the case. Nor have we yet learnt that these things are managed any better by the War Deparment, for if Shoeburyness could testify to anything at all, it would to the failure of the first trials with the Palliser bolts, notwithstanding all the pains that had been taken to insure success by previously testing the iron, and by all other available means. But to revert to the use of elastic cup washers, we think it only fair, after what has been said on the other side of the question, to give some positive proof of their utility from actual experiments made at Shoeburyness, for Major Palliser himself did not appear to be in full possession of all the facts of the case when he read his paper on Armor Fastenings at the annual meeting of the Institution of Naval Architects, in 1867. Otherwise, we are at a loss to account for his statements, especially during the discussion which followed, for he then appeared not to be able to recollect anything good of these washers as compared with his own plan. For instance, when asked if the bolts he had been referring to had elastic cup washers, his reply was, that the "box-target" was fitted with them, and they were nearly all broken. Now, what is the history of this old target? We call it old, because in one sense it was never new, having been constructed entirely

out of old materials, as the following statement will show:

The Ordnance Select Committee, at the time we are referring to, having a number of projectiles to test, and being anxious to economize as much as possible, resolved to use up all the old materials then lying on the ground at Shoeburyness that were available for the purpose; consequently old bolts, old cups, and old india-rubber were among the things that were brought into requisition. The bolts and washers were the same as had been used at the trial of the Bellerophon target, and had done their work successfully, not one of the bolts with these washers applied to them having failed on that occasion. In order to render these very bolts available for the "box-target," not only had they to be repaired, but also lengthened. Hence it could not be expected that they should stand as well as new bolts and washers, and no one who had anything to do with the construction of this target ever dreamt that any notice would be taken of these fastenings. In fact, it was distinctly understood officially that the sole object of the erection of this target was the trial of projectiles. Let us, however, inquire what was the state of the target at the time referred to by Major Palliser?

When we last examined the structure to ascertain the amount of damage it had sustained after three days' firing from the Woolwich 7-inch rifled gun, at a range of 200 yards, we found it had received 22 rounds in a space 13 ft. 6 in. × 8 ft. 6 in., which were the dimensions of the target proper. We need scarcely tell our readers that it was knocked nearly all to pieces, and the marvel was that any bolts should have been discovered unbroken. However, we could only find seven out of twenty that were *broken*.

Major Palliser also attributed the partial success of these washers to the very fine threads he had introduced on some of the experimental bolts. We, however, apprehend that he referred to an experiment that was made with cork washers against his system, when it was considered only fair that the bolts should have one uniform thread.

We shall presently have occasion to allude to these experiments. At present, however, we shall only say that the Admiralty does not recognize any other elastic cup washer than those with india-rubber, and up to the present time there has been no trial of these in competition with the Palliser bolts, nor has the Admiralty adopted the very fine threads.

When Major Palliser read his paper on Armor Fastenings, only two experimental trials with the elastic cup washers had been made under the direction of the Admiralty. The first took place with the Bellerophon target in February, 1864. One half of the bolts had common plate washers and double nuts, and the other half had the elastic cup washers and single nuts,* and the bolts were 2½ ft. and 2¾ in. diameter respectively, with about five threads to the inch. The result of one day's firing, which was all this target was subjected to, was the breaking of two bolts with the common plate washers. None of those with elastic cup washers were injured. The comparative success of this trial with the bolts was attributed to the strength of the target not allowing the plates to buckle so much, and the bolts being comparatively of larger diameter.

The other experimental trial was a more important one. It took place on the 29th August and 14th September, 1866, with one of the Warrior targets, being the same in all respects as those previously fired at when the bolts so signally failed; as many as from 6 to 9 breaking in one round. There were 51 bolts in all driven in this target, 25 of which were fitted with elastic cup washers, and the same number with Paget's steel spring washers, the odd one having a common plate washer only. The result after two days' firing was as follows: Eighteen bolts with steel spring washers were broken; the odd bolt having a plate washer was broken at the first round. Not one of the bolts fitted with elastic cup washers were broken.

With these facts before them, how could the Admiralty do otherwise than adopt their present system? Bolts with ordinary plate washers had utterly failed, and no other system of fastening had proved so successful as the elastic cup washers.

The success of the above trial was considered all the more conclusive on account of the bolts having been driven into and out of another Warrior target, a fac-simile of the one we have just described, the elastic cup washers having been under heavy pressure for 22 months at Shoebury-

* It was the practice, before the introduction of elastic cup washers, to use lock nuts, owing to some of the single nuts flying off at the moment of impact by shot, but the spring in the cup washer obviates the necessity for double or lock nuts, as it keeps the single nut tight on the bolt.

ness, exposed to all sorts of weather. This circumstance occurred through the Ordnance Select Committee at that time determining that three other systems of fastenings should take precedence of trial, there being no other target available. These we may mention were Palliser's, Head and Ashby's wire bolts, and the common ones with Clarkson's cork washers fitted to them; some of the latter having iron cups similar to those used for india-rubber. These three sets of bolts had very fine threads, as many as 16 to the inch, and so delicate were they, that it was with great difficulty the bolts could be driven without injuring them. The result of this trial proved that the Palliser bolts and those fitted with cork washers were about equal as regards efficiency, while Head and Ashby's wire bolts signally failed. Clarkson's cork washers were found, however, not to answer the same purpose as india-rubber; there being comparately no lateral extension with this material, iron cups were therefore not needed. In addition to this, the cork became as hard as wood, by simply screwing up the nuts. No doubt the very fine screw threads, together with a more ductile and costly iron, considerably improved the bolts.

We are not in possession of the details of these three experiments, and therefore we cannot say whether any of these fine screw threads stripped during the firing. We merely advert to the trial of these bolts on account of its historical connection with the one just described.

We have hitherto confined our remarks on the Palliser bolts to their applicability to ships' sides; but as we wish to give an unbiassed opinion upon the whole question, let us consider lastly the advisability of adopting them in turrets where watertightness is not so important. It will, therefore, be necessary for us to inquire what thickness of wood backing will have to be provided for; and here we may at once say, that if the same arrangement as that now adopted for the Cyclops class of turret ship should be proposed as the one to carry out this particular system of fastenings, it will be impracticable, for we do not suppose that the country would like rickety turrets any more than they appear to like rolling ships. But with a backing similar to that of the Warrior, of, say, 18 in. thick, it might be arranged thus by allowing the bolts to have a length of 6 in. for stretching in the middle of their shanks, with the same length of hold in the wood backing at each end. The form of bolt in this case, however, would have to be modified in order to reduce their points for driving. A drift of ¼ in. for a 3-in. bolt is generally allowed, to insure tightness.

In the latest turret ships the armor is, we believe, to be arranged in two thicknesses, with a layer of wood backing between them, and a second layer of wood between the inner armor plates and the skin plating. In wake of the inner armor the shanks of the through bolts are to be reduced to give spaces for stretching; but they will maintain their full size through the outer armor, and both thicknesses of backing. The use of elastic cup washers will be continued, and thus the two systems of fastenings will, to some extent, be combined.

AN ANALYSIS OF THE COST AND DESCRIPTION OF THE METHODS OF MINING EMPLOYED IN THE MARQUETTE IRON REGION, LAKE SUPERIOR, MICHIGAN.*

By MAJOR T. B. BROOKS, C. E.

The product of the Marquette Mines has nearly doubled during the last four years, and is now about 825,000 gross tons of ore, which will yield on the average 62½ per cent. of pig iron in the furnace; hence, during the last two years, fully one-fourth of all the pig produced in this country has been from Lake Superior ores. About 66 per cent. of the shipments are specular hematites, yielding 65 per cent. of iron; 17 per cent. are magnetic ores, yielding 65 per cent. of iron; 13 per cent. are soft hematites, yielding 50 to 55 per cent. of iron, and 4 per cent. second class specular ores, yield-

* This paper, written in 1870, forms a part of the 2d article of the Chapter on Mining of the writer's unpublished Report on the Geology of the Marquette Iron Region. A portion of the 1st article relating to the geological structure of the ore deposits, and a discussion of the general mining problem presented, was read before the American Institute of Mining Engineers. That paper contained a skeleton of this. A paper read before the American Society of Civil Engineers.

ing, say 57 per cent. of iron. One hundred and twenty-five furnace stacks use Lake Superior ores wholly or in part; of these, 89 employ coke or bituminons coal as fuel, 10 anthracite coal, and 26 charcoal. The charcoal furnaces are all small, seldom producing over 5,000 tons per annum. Eighty of the bituminous and coke stacks are in Ohio and Pennsylvania; all the anthracite stacks are in Pennsylvania and New York, and over one-half of the charcoal furnaces are located in Michigan. The iron produced is soft and strong, answering equally well for mill or foundry use. It inclines to red-shortness, without being decidedly red-short. It is too soft for rail-heads, but is unequalled for the base of the rail and for merchant bar, and is now being successfully used for Bessemer steel.

The geological structure of the iron-bearing rocks is such as to render quarrying in open cuts the favorite method of extracting the ore. The ore formation is made up of pure ore associated with lentiform masses of a soft green schist and of jaspery or mixed ore. The overlying rock is quartzite, having a specific gravity of 2.67, and the foot wall rock a diorite or greenstone, having a specific gravity of 2.91. The merchantable specular and magnetic ore has a specific gravity of from 4.59 to 5.00, averaging 4.85, weighing therefore about 300 lbs. to the cubic foot, or $3\frac{5}{8}$ gross tons per cubic yard. Seven and a half ft. of solid ore and about 15 ft. of loose ore, as it is sent to market, weigh one gross ton. The specific gravity of the "mixed ores" varied widely, depending on the amount of jasper, the average being about 3.75. The soft green schist associated with the ore has a specific gravity of 2.82.

The unit of measure and comparison in the following table is the gross ton of merchantable ore. The ore is the object of the miner's efforts, and the tons sold measure his business. The items of cost in all that follows express the expenditure per ton of ore mined, prepared for market, and loaded on the cars. In instituting a comparison between these figures and those obtained by the civil engineer, where the cubic yard of vacant space is the ordinary unit of work accomplished, it must be borne in mind that the labor incident to sledging up and sorting out the ore from the rock considerably enhances the cost of mining.

The wages of the men employed in and about the mines, in 1869 and 1870, were about as follows: Common labor was nominally $1.80 per day for most of the time, but by far the largest part of the mining work was done under contracts. Contractors made, clear of cost, from $60 to $77 per month as high and low averages; $70 is probably near the mean of the whole. It is not uncommon for a "pair," two or more men, to make $100 per month each, and again the earnings will fall so low as barely to pay board; but such are extreme cases.

Leaving out the staff of the mine and the contractors, the average wages of all others, mechanics, engineers, firemen, drivers, but mostly common laborers, averaged for the period in question about $2.12 per man per day. Mechanics received from $2.50 to $4.00. The nationality at three mines, which employed an aggregate of over 600 men, was as follows, expressed in percentages:

Irish	31
English (Cornishmen)	27
Swedes	18
Canadians (French)	5
Americans	5
Germans	4
Norwegians, Danes, and Scotch	10
	100

The relative proportion of the Irish element is decreasing; a few years since nearly all the men employed at some mines being of this nationality. The percentage of Cornishmen is increasing, owing largely to a want of work in the copper region. These men are skilled miners and do a large part of the sinking and drifting. Swedes are rapidly gaining in numbers, many of them having been miners in their own country.

The $2.64 given in the following table as the approximate total cost of the hard ores, delivered on the cars at the mine, was obtained by dividing the total expenditure at the mine for a year, by the total number of tons of ore produced. It does not include interest or capital, nor royalty, or depreciation of the mine.

In the detailed description of methods which follow, the items will be taken up in the order of the table, omitting such as are unimportant, or do not possess the kind of interest that warrant their introduction here. The whole subject will be considered more fully in my report on the Lake Superior Iron Region.

1. Dead Work.—This general head embraces all the work and cost incident to getting ready to mine the ore, and is subdivided into—1. Explorations (embracing

only such searches for ore as are in progress from year to year about the mine). 2. Sinking Shafts. 3. Drifts and Tunnels. 4. Roads for Wagons. 5. Stripping Earth and Rock, or uncovering the ore. 6. Miscellaneous Work and Minor Improvements. Only the 2d, 3d, and 5th items will be considered, the character of the others being sufficiently indicated in the table. The entire expenditure for dead work is 74 cents per ton of ore produced, which equals 28 per cent. of the whole cost.

Table showing the Approximate Cost of Mining the Specular and Magnetic Ores of Lake Superior (to accompany Major T. Brooks' paper on the subject.

General heads under which cost of mining is classified.		Elements of cost, not including royalty or depreciation.	APPROXIMATE COST OF EACH ITEM. In per cent. of the whole. Items.	Totals.	Based on a total cost of $2.64 per ton. Items.	Totals.	Amounts. Labor.	Supplies.
I. Dead work (preparation)		1. Explorations	.006		.015		Eighty per cent.	Twenty per cent.
		2. Sinking Shafts	.015		.040			
		3. Drifts and Tunnels	.061		.160			
		4. Roads	.006	.281	.017	.742	.620	.122
		5. Stripping earth and rock	.132		.350			
		6. Miscellaneous work and minor improvements*	.061		.160			
II. Mining proper (labor).	Drilling.	1. Ledge holes (in stope)	.042		.110			
		2. Block holes (in fragments)	.049		.130			
	Other work.	3. Sledging, sorting, and loading	.133	.398	.350	1.050	1.050	.....
		4. Handling rock	.095		.250			
		5. Miscellaneous work	.079		.210			
III. Mining materials and implements ("mine costs").	Explosives	1. Powder and fuse	.036		.095			
		2. Nitro-glycerine	...†		...†			
	Tools.	3. Steel (drills)	.007	.119	.018	.313	.103	.210
		4. Tools other than drills	.016		.043			
	Repairs.	5. Blacksmiths' supplies	.018		.047			
		6. Blacksmiths' labor	.042		.110			
IV. Handling ore from miners' hands to cars, and pumping.	By horses.	1. Teaming, labor of drivers and stablemen	.057		.150			
		2. Forage	.042		.110			
		3. Carts, sleds, harness, &c.	.002	.156	.006	.413	.272	.141
	By men.	4. Loading ore from stock pile	.013		.035			
	By steam.	5. Labor, supplies, and repairs	.042		.112			
V. Management and general expenses		1. Salaries and office expenses	.046	.046	.122	.122	.062	.060
		2. Tax of all kinds						
			100	100	2.64	$2 64	$2 107	$0.533

2. Sinking Shafts.—This work, which forms so large an item of cost in some underground mines, varies in the Marquette Region, so far as I have ascertained, from 1½ to 5½ cents per ton of ore. Our open and comparatively shallow workings do not call for many shafts or winzes; the deepest shaft in the Region is now (1870) not over 200 ft. The prices for this work range from a mean $22.50 to $31.50 per ft. in depth, depending on the hardness of the ground. In some mines, extreme prices range from $15.00 to $40.00; or even more, if the shaft be very wet. Miners are often permitted to select the size most advantageous to themselves, which may be 4 ft. by 6; but 8 by 12 ft. is more common. The material is generally hoisted with the ordinary hand windlass, but sometimes with a horse-whip or whim. The miner has to

* Does not include exceptional permanent improvements.
† No reliable figures obtained.

deliver the stuff at the mouth of the shaft. From 10 to 15 per cent. of the price received by the miner for sinking, has to be expended in costs; *i. e.*, powder, fuse, candles, steel, tools, etc. No charge is made against him for smith's work. Sometimes the contract is let at so much per foot of shaft and so much per ton of ore, which gives the miner an interest in separating ore from rock.

3. Drifts and Tunnels.—This element of cost varied more widely than any other, and might have been divided into two: (1) Drifts designed to open ground for stoping, and (2) Tunnels or adits for drainage and transportation of ore, the latter being of the nature of a permanent improvement. But on the principle that permanent improvement accounts are often permanent disappointment accounts and to be avoided, and considering the fact that this work is actually going on year by year, and must do so as long as the mine is worked, it does not seem wise to separate it from the actual cost of getting ore. Ordinary 4×7 drifts cost, in hard ore, from an average of $22.50 to $24.50 per ft., the miners delivering the material behind them and paying their own costs as in the case of shafts.

Tunnels large enough to admit railroad cars and small locomotives, cost from $30.00 to $50.00 per ft. The Washington Tunnel, now over 1,100 ft. long and timbered considerable part of the way, cost an average of about $40,000, not including rails. The timbered portion is 12 ft. wide at the bottom, 10 ft. at the top, and 10 ft. high in the clear. No machinery has yet been brought to bear on either sinking shafts or drifting; the labor is more than one-half expended in drilling holes for blasting. The subject of drilling is fully considered under its proper head.

5. Stripping earth and rock, or uncovering the ore.—This constitutes on the average nearly one-half of the dead-work, and is one of the largest single items in the whole cost of mining. So far as my inquiries extended, I found it to vary from 20 to 52 cents per ton of ore. This cost is necessarily increasing at all of the mines worked as open cuts. It is simple rock and earthwork, the material being removed on wagons, carts, or sleds, drawn by horses. The advantages of light railroads and small locomotives do not seem to have commended themselves for this work. There would of course be considerable danger of destroying tracks from blasting, and it often happens that not much work has to be done in one place; still there is no doubt but that a large saving would be effected by substituting steam for horses in this work, as will be more fully considered hereafter.

The aggregate amount of material which has been handled in stripping is very great; 30, and even 40 ft. of earth have been removed, and nearly as great a depth of rock; but this is the experience in open workings everywhere. I have seen 21 ft. of earth and soft, shaly rock stripped from a nearly horizontal bed of 44 per cent. Clinton ore in Western New York, which did not average over 30 in. thick. In South Eastern Kentucky I found the rule among the miners of sub-carboniferous ores to be, that it would pay to remove a foot of earth for the sake of an inch of ore, which does not differ widely from the Western New York practice. In both of these instances the stripping was nearly the entire cost of mining, and labor was much lower than in the Marquette Region. The usual contract price for removing ordinary earth (sand, clay, and boulders mixed together) is 50 cents per cubic yard, the digging costing about one-half and the handling one-half. Hauls vary from 100 to 800 ft. The highest price paid for excavating any considerable quantity of rock in open cuts, which has come to my notice, was $3.00 per cubic yard, equal to $24.00 per fathom, or about $1.00 per ton. This was a very hard jasper rock containing but little ore. Large quantities of rock have been excavated and hauled over 500 ft. at the Lake Superior Mine for $2.50 per yard. The soft greenish schist, so common at all the mines, can be moved for from $1.00 to $1.40 per yard including hauling. When a good face can be obtained on the overlying quartzite, which is likely to constitute the greater part of the rock to be moved in future, it should be broken down and loaded on wagons for $1.50 per cubic yard.

The amount of money which it will pay to expend in stripping, of course, depends chiefly on the quantity of ore uncovered. If we assume 50 cents to be the maximum expenditure per ton of ore for this work (this amount has been exceeded), the problem of what thickness of rock may be stripped admits of an easy theoretical solution. One cubic yard of solid ore, allowing for wastage on account of associated rock, may be considered to yield 3 tons of merchantable ore, which, at the allowance above assumed,

would give us $1.50 to be expended per square yard in stripping a bed of ore only one yard thick. Hence in this case it would pay to remove 9 ft. in thickness of earth or about 3 ft. in thickness of rock. But suppose we have a bed of ore 24 ft. in vertical thickness, which is a more common case, what amount of rock or earth would it pay to remove under the assumed limit of expenditure? 24 ft. of ore gives 24 tons per square yard of surface, which, at 50 cents per ton, gives $12.00 available for stripping per square yard. This sum would remove 24 ft. thickness of solid rock; or a foot in thickness of rock may be stripped for every foot in thickness of ore uncovered, at a cost of 50 cents per ton of ore. The same expenditure will remove three times this thickness of earth.

An important and often neglected question connected with this subject is, where to deposit waste, that it may be out of the way of future mining operations. Some material has been already handled twice in the Marquette Region, and I know of a mine in Southern New York, where the same earth has been three times handled before it was finally put out of the way. In a new region, like Marquette, where comparatively little thorough exploring has been done, it is often difficult to decide where waste piles will be out of the way for all future time. If a drill hole were put down for 50 ft. in rock and no ore found, it would be safe to say that if ore existed under that spot, it would have to be mined under ground; hence, that so far as future stripping was concerned, a waste pile placed there would be out of the way. A very common practice in under-ground work, in some mining regions, is to fill up the worked out places with waste, and this can undoubtedly be done to advantage in some instances in open works, although it has not as yet been practised in the Marquette Region. The trouble is, to find out when a pit is exhausted—it is so common to break through a thin layer of rock and find a bed of workable ore under it. But there are parts of most mines where the foot wall has unquestionably been reached, and if any doubt exists, a few deep drill holes will settle the point. When this is the case, and the foot wall has a sufficiently gentle slope to permit of its holding materials deposited on it, it will, I think, be often found advantageous to use it to support a waste pile.

For the sake of illustration, take the New York and Cleveland Mine workings, which are adjacent. In this instance the slope of the foot wall is so steep that it would probably require a rude step to be cut on which to rest a rough retaining wall, built of blocks of quartzite swung across from the hanging wall by means of a derrick. The triangular space thus formed would hold all the waste rock for a long time to come, and would afford a minimum haul. It might not answer to deposit earth in such positions, as heavy rains would be likely to wash it into the pits. The dip of the foot wall in this, as well as in most cases, will I think become flatter in depth, so that a better opportunity will be afforded for a second similar waste receptacle at greater depth, if one should be required. This plan would also have the advantage, when under-ground work is begun, as it soon will be, of affording a good support to the roof of the mine.

II. Mining Proper, or Breaking Ore.—This general head embraces all the labor incident to blasting the materials down from the solid ledge and breaking it up into fragments that may be easily handled, and the separation of the ore from the rock by hand. The average cost under this head is $1.05 per ton of ore produced, which equals forty per cent. of the whole. The character of this work will be sufficiently well understood from the table and the following explanation:

1. *Ledge or Stope Holes.*—The drilling or rock-boring is now entirely done by hand. The steel used for drills is 1¼ in. octagon with a bit 1½ in., making a hole nearly 2 in. in diameter. Drills vary in length up to 24 ft. English steel is used at some mines, but a majority use American steel, and the most experienced men who have used both inform me that the drill steel made by Hussey & Wells and Parke Bros., Pittsburgh, is about as good as the best imported steel, and much better than the average. The drill is turned by one man sitting and struck by two standing, with 8 lb. hammers, at the rate of thirty-six blows per minute each. In this way from 9 to 11 ft. of hole are sunk per day, the men working usually on contract. The price of stope holes ranges from 60 to 80 cents per foot in depth, the mean being not far from 75 cents; no mine costs have to be paid out of this price. When there is a large proportion of block holes, which admit of the use of smaller steel, the whole

drilling of a pit is often let at from 60 to 65 cents. Very deep holes, say from 15 to 22 ft., are sometimes sunk with 2-in. bits, which about doubles the cost. In these cases, two men sometimes turn the drill and three strike.

The cost of drilling ledge holes per ton of ore, varies from a mere trifle in the case where one 22 ft. hole throws down 4,000 tons, as has been done to a very large item on low stopes with perhaps tight, hard ground. From three (3) cents to 25 cents per ton may be regarded as extreme averages, although 35 and even 48 cents have been reached, for short periods, under very unfavorable circumstances. The price given in the table (11 cents) approximates to the average for hard ores; this number, divided into 75 cents, the average cost of drilling per foot, gives say 7, which should represent the number of tons of ore broken per foot of hole drilled. The data obtained directly under this head confirms this amount, which is equivalent to about two cubic yards per foot of stope hole.

The depth of stope holes varies from 2 to 22 ft., the short ones being employed in "taking up bottom," that is, in squaring the stope so as to give the best chance for the deep holes. The average of 1,500 stope holes of all kinds in one part of the Washington Mine was 4 ft. 9 in., but the stopes which furnished this result were below average height. It is believed that 9 or 10 ft. would be nearer the average for deep holes, and say 3½ feet for the short ones.

2. *Block Holes.*—The masses of rock and ore loosened by the heavy blasts already described, are often so large that they have in turn to be broken with explosives, which operation is termed block-holing. The amount of this work varies from almost nothing in some pits and some mines, to four-fifths of all the drilling required in others, the maximum being reached on high stopes of hard tough ore. Over two hundred block-holes have been required to one stope hole in the Cleveland Mine, one hole being required to every 2 to 4 tons of ore. Block-holes sometimes produce fragments so large as to require block-holing in turn, before they are made small enough to be mastered by the sledge. Block-holes vary in depth from 8 to 24 in., the mean ranging near one foot. With nitro-glycerine the holes need not be so deep as for powder. One-inch octagon steel is used in this work, making a hole nearly 1½ in. in diameter. The drilling is performed as in the case of deep holes, but usually only one man strikes.

In the same ground, the same drill gang will sink more than twice the number of feet of block hole in a day with small steel, than of stope hole with large steel—ranging from 24 to 27 ft. In open mines of strictly hard ore this work costs more than stope holes, and is set down in the table at 13 cents per ton. This amount, added to the 11 cents given as the cost of stope holes per ton, equals 24 cents for the total cost of the labor of drilling required under breaking ore: this would equal about 70 cents per cubic yard, which would pay for 1 ft. of 2 in. drill hole. But this is by no means the whole; the work of sinking and drifting, which is set down as aggregating 20 cents, is more than half drilling; and a part of the cost of rock stripping is also for this work. I estimate that 40 cents per ton of ore is not far from the actual price paid for this kind of labor in the hard ore mines, equal to 15 per cent. of the whole cost. On this estimate, not less than $300,000 were paid out for drilling in 1870. This work, from the favorable circumstances under which much of it is done in open excavations, no scaffolding being required, is by far the most mechanical labor performed about the mine. While the absolute cost of this item of drilling is very large, and can undoubtedly be reduced by the use of the power-drill, it is, as compared with some other mines and regions, small. Our open cuts or quarries afford far better facilities for blasting than underground mines. In one Southern New York mine the drilling cost, in 1870, $1.25 per ton of ore, or 40 per cent. of the whole cost of mining; in a large magnetic mine in New Jersey, it cost from 60 to 80 cents per ton of ore. In the Presberg mines, Sweden, when the ore cost, in 1870, $2.20 currency per ton, the drilling was 40 cents per ton, equal to 23 per cent. of the whole cost, being considerably more than ours absolutely and relatively. When we consider that the average wages in Sweden is not far from 50 cents per day, or say ⅓th of what is paid Lake Superior miners, it would seem as if Sweden would be a good field for a power-drill.

3. *Sledging, Sorting, and Loading.*—In considering this item, it must be borne in mind that the ore and rock have not only to be broken so that they can be removed, but so fine as to be easily separated, and so

that the pieces can be fed into a Blake crusher. This work requires more muscle and as much skill and care as any other done at the mine. Twenty-three-pound sledges are employed, and the difference in results, between the experienced miner who strikes the lump of ore the right blow in the right place, with this immense hammer, and the tyro, is very great. Contracts for sledging and loading, sometimes including a little lock-holing and short tramming, have been let at prices varying from 20 to 50 cents per ton. The loading usually costs not to exceed 10 or 12 cents, the balance being chiefly sledging. There is a wide difference in the texture of ore, some kinds requiring five times as much sledging as others. On the whole, Marquette ores break with much greater difficulty than those of the Eastern magnetic mines. With poorer ground worked and the market more in favor of buyers (which makes them more exacting on quality), the cost of this element will be increased.

III. Mining Materials and Implements, embracing "Mine Costs."—This general head is subdivided in the table into Explosives, Tools, and Repairs, which are in turn itemized, as will appear below. The expense incurred under this head is 31⅓ cents per ton of ore produced, equal to about 12 per cent. of the whole cost.

1. 2. *Explosives.*—Powder and fuse and nitro-glycerine. The present (1870) is an unfortunate time to collect statistics regarding the cost of explosives, for the reason that nitro-glycerine is on trial, and most of the mines employ both it and powder in the same pits, making it difficult to separate the results. The place of the new explosive cannot be said to be fixed in our mines. It is more powerful than powder, bulk for bulk, or weight for weight; can be used in wet as well or better than in dry ground, which is very important in some places; it has so far proved no more dangerous than powder, and its fumes have not been found objectionable. As has been stated, the fragments resulting from its use are usually smaller, hence require less sledging, and it being more powerful than powder, less drilling is needed. I have not sufficient data to institute a comparison between it and powder for general use; for very wet or very tight ground, and for much of the sinking and drifting, it answers better than powder. Whether it is suited to breaking the great masses from the solid ledge remains to be seen. Certainly it cannot be used to fill the cracks produced by shaking, when heavy sand blasts are required; and it is doubtful whether drill holes large enough to contain the requisite amount of the blasting oil can be profitably employed. It certainly costs *more* per ton of ore mined than powder, but how far this greater cost is balanced by other advantages remains to be seen. It is significant that in 1870, being the next year after its introduction, over $70,000 were sold in the Marquette Region at $1.50 per lb. The Painsville (Ohio) Co. have erected (1871) a factory near Marquette. No other explosives than powder and nitro-glycerine have been used.

The figures given in the table, and what follows, refer exclusively to powder, the nitro-glycerine element having been eliminated as far as was possible. Fuse costs about ½ a cent per ton, which leaves 9 cents per ton for powder, which according to the data obtained varied from 7 to 10 cents. The price of powder ranged from $3.75 to $4.50 per keg of 25 lbs. Therefore an average of 45 tons of ore should have been broken with one keg of powder, or about ½ lb. of powder to one ton of ore. This, it must be remembered does not express the actual work of the powder, on account of the amount of rock moved in addition to the ore—in one instance 23,000 weighed tons of material required 320 kegs of powder, or 72 tons per keg. In another instance 31 kegs threw down 3,500 tons (approximate) of quartzite, or 113 tons per keg. One mine which produced over 100,000 tons of ore in 1869, consumed for all purposes one keg of powder to every 43 tons of ore produced.

The waste material in this case did not amount to over 20 per cent., hence about 52 tons, or, say, 18 cubic yards of material, were moved per keg of powder. The consumption of explosives per ton of ore must increase as the mines grow deeper, either by the greater amount required to remove the rock covering, or by the less favorable opportunity afforded for blasting, if the ore be won underground.

In one group of New Jersey mines, the powder and fuse cost 18 cents per ton; in another mine in Southern New York 14¼ cents; in Sweden, at the Presberg mines, 15 cents. All of which figures considerably exceed those reached in Marquette, which is an additional proof of the economy of

working iron mines as open quarries as long as possible.

3. *Steel.*—The use of steel drills has already been described, and reference made to the brands in use. My data, which are far from complete under this head, indicate that the cost of steel per ton of ore ranges from $\frac{3}{4}$ to $3\frac{2}{10}$ cents, averaging perhaps $1\frac{8}{10}$ cents; the price of steel being 20 cents per lb. This would give about 11 tons of ore, or about 3 cubic yards per lb. of steel consumed, which is less than the data obtained direct on this point seemed to indicate.

It is the practice at some mines to charge the ore contractors 2 per cent. on their contracts for wear of steel, which agrees nearly with the above. At other mines the steel is weighed at the end of each month, and the contractor charged with the shortage, whatever it is.

IV.—Handling Ore from Miners' Hands to Cars and Pumping.—The pumping which has heretofore been a small item in the Marquette Region, could not well be separated from the hoisting of ore, as the same machinery does both. This item in the case of some New Jersey magnetic mines costs 75 cents per ton of ore; at the Presberg mines, Sweden, it costs but 7 cents. The entire cost under this head, including hoisting and pumping, is 41 cents per ton of ore produced, which equals $15\frac{1}{2}$ per cent. of the whole. This work is done in part by horses, part by men, and part by steam.

1, 2, 3. *The work of horses in handling ore.*—The team work employed at the Marquette mines, apart from the stripping, amounts, according to my inquiries, which have been quite full on this point, to 10 per cent. of the whole cost of mining, or say 27 cents per ton, the drivers' wages being the largest item. This cost is obtained by dividing the total expenditure for teaming by the total number of tons of ore produced. If it was figured only on the ore actually handled by horses, it would be much greater. If to this were added the cost of the team-work employed in stripping, the total would not be less than 30 cents per ton of ore, or say $250,000 on the product of 1870, a sum sufficient in itself to supply all the mines in the region with all the additional steam hoisting and pumping machinery and small locomotives required to do the work now done by horses, and at a very much less yearly cost. We may verify this almost incredible estimate in another way. The total number of horses employed at all the mines in 1870, including hired teams, averaged about 364, or 30 to each mine, varying from 9 to 74. The best data I could get indicate that to run a lot of horses for one year, including wages of drivers, stable-men, smiths' work, forage, repairs of vehicles and depreciation, in the years 1869 and 1870, cost an average of $650 per horse. The wages of hired teams, including drivers, for the same period, was $6 per day. At this rate, 364 horses would have cost nearly $240,000, a sum sufficiently near the other to confirm the general truth of the estimate.

These figures surely justify the prediction, that if there ever comes a period when our mines do not pay, it may be due largely to horses. In this age of steam, has a business any just right to prosper which employs horses to do work that can be done more cheaply by machinery? The average number of tons of ore handled per horse employed in and about the mines for all work in 1870 was 2,350, ranging from 1,150 to 5,300 tons. In considering these facts it must be borne in mind that the mines in question are not by any means without steam power. Twelve engines, varying in power from say 10 to 50 horse, were at work. To prove that this item of cost is unusally large in the Marquette Region, I will give a few facts regarding the employment of live stock at mines, which have come under my notice elsewhere. While the cases cited do not present all circumstances like the Marquette mines, they are sufficiently near to afford interesting comparisons.

The Cornwall Ore Bank Company, Pennsylvania, shipped from their one immense deposit, in 1870, over 174,000 tons, employing no horses in the work. The ore was all handled by one locomotive, the cars being loaded by wheelbarrows. No pumping is required in this mine, and the facilities for reaching the ore with cars are unusually good. The ore is quite soft, so that the blasting does not endanger the tracks.

The Iron Mountain Mine, Missouri, shipped, in 1870, more ore than any one mine in the Marquette Region. It employed, during the winter 68, and during the summer, a somewhat less number of horses and mules. One animal moved about 12 tons per day, or 3,600 tons per year; but more than three-fourths of this stock was employed in getting "surface ore," a feature which does not exist in Marquette mining. The bluff (quarried) ore moved per horse em-

ployed, was more than five times the above amount. No steam engine or locomotive was in use at the mine.

At the Caledonia and Keene mines, St. Lawrence County, New York, in 1869, three horses handled 27,500 tons of ore and waste, the average haul being over 700 ft. all up grade, in places steep. This gives over 9,000 tons per head; steam was not employed for handling material at either mine.

The Sterling mine, Orange County, New York, shipped, in 1869, 40,000 tons of ore, which was handled under circumstances quite similar to those encountered in the Marquette Region, by two horses and one small stationary engine, which gives 20,000 tons per animal employed. The system of tramways and sidings at this mine is very complete.

Passing from American to Swedish mines, which are far deeper, and in which there is a larger percentage of rock mixed with ore, we find that in the Presberg mines, in 1870, the total cost for handling ore and water-drawing, was $14\frac{3}{4}$ per cent. of the whole cost, or 33 cents per ton of ore; and this amount included the handling of all the rock and other waste material, which in our table is embraced under *Dead-work*. If we take out of dead-work 10 cents for handling the waste material, and add it to the amount found above, we have 51 cents as total cost of handling Lake Superior ores, equal to 20 per cent. of the whole cost, or about 50 per cent. greater than in the Swedish mines, where steam and water are exclusively used.

5. *Machinery for Pumping and Hoisting.*—Notwithstanding the great cost of the work of horses, a large amount of machinery, as has already been remarked, is now in use, eight out of the eleven larger mines having more or less complete plants. (1870.)

The introduction of machinery has so far seemed to make but little relative diminution in the number of horses employed, because of the greater amount of waste material which has to be moved in the later years. The figures given in the table opposite this item, $11\frac{2}{10}$ cents, is designed to be an approximation to the cost of running the machinery of such mines as have plants distributed over the entire product of those mines. I estimate that less than one-half of the product of such mines was handled by machinery in 1870. The actual cost of the ore so handled, including the *pumping*, varied from 14 to 21 cents, the mean as shown by my data being about 18 cents. This cost is made up of wages of engineers and firemen, say 15 per cent.; fillers, landers and surface tramming 60 per cent.; fuel, repairs of machinery and supplies, say 25 per cent. This covers cost from miners' hands to cars or stock pile.

While this sum is materially less than the cost of the same work by horses, it is much greater than in the Copper Region of Lake Superior, where this business is brought to great perfection. Some of the appliances employed in the Copper Region can not be used at iron mines on account of the greater irregularity of the deposits. But time will introduce many economies, which will reduce this cost below the figures given. It must be borne in mind in comparing the cost of steam machinery with horses, that in the case of the engines all the pumping is included, while the horses handle only the ore. Making this correction, it is safe to say that it costs at least four times as much to handle the same ore by horses as by machinery.

The following described machinery plant has been recently erected at the New York mine, and will give a good idea of the kind in use. It consists of one steam engine with cylinder 16x24 in., with bed cast solid in one piece. Valve is of the kind known as the H-valve, and is worked by link motion; steam pipe 4 in. in diameter, exhaust pipe 6 in. in diameter; engine supplied with the Judson governor. Pump for feeding boiler is worked from crosshead. Main shaft is 5 in. in diameter, of hammered iron, and 6 ft. long. One boiler 42 in. shell, 21 ft. long, with two 14 in. flues. Smoke stack is 35 ft. high and 20 in. in diameter. The winding drums are 4 ft. in diameter, and of sufficient capacity to contain 525 ft. of $1\frac{1}{4}$ in. wire rope. They are worked by positive clutch movement, thrown in and out of gear by means of hand wheels attached to lever by pinion and gear. The brakes are known as band brakes, which clamp the entire surface of the drum 5 in. in width, and are of sufficient power to hold a loaded skip at any point in case of accident. They are worked by levers with hand or foot, as may be desired. The drums make about $13\frac{1}{2}$ revolutions per min., the engine making 80, which gives the skip a speed of a trifle less than 3 ft. per sec. The skips are of heavy boiler iron, each having four 12 in. wheels. The capacity of each is 18 cubic ft., equal

to about 1¼ tons of ore. The pump is 8 in. in diameter by 6 ft. stroke, capable of discharging 243 gallons of water per min. It is worked from a slotted crank arm, on end of main drum shaft, which admits of lengthening or shortening the stroke at pleasure. The pump is double acting with single valve on a new place. It is furnished with rods, travellers, connections, balance bobs, etc. This machinery was furnished complete in all its parts and set up at the mine in complete order for pumping and hoisting for $6,000, by the Iron Bay Foundry, Marquette, Mich., 1870.

V. Management and General Expenses.—This covers only those expenses in the mining region, and not salaries of officers above the superintendent, nor the cost of selling the ore.

1, 2.—*Salaries, Office Expenses, and Taxes.*—This element of cost constitutes less than 5 per cent. of the whole cost of the ore, amounting to about 12 cents per ton. I am happy to note here a much better showing than in the Presberg Mines, Sweden, where this item, in 1870, cost 16½ per cent. of the whole, or 36 cents per ton of ore; nearly three times its cost with us. I presume the excess of this item in Sweden may be largely due to heavier taxes.

COSTS OF NARROW-GAUGE RAILROADS, FROM SURVEYS AND CONSTRUCTION.

From the "Chicago Railway Review."

The estimates herein presented of the cost of preparing the road-bed ready for the iron, with a gauge of 5 ft. (the standard gauge of the South) and a gauge of 3 ft., have been made with great care from the final location surveys of the First Division of the Memphis & Knoxville Railroad, for which they were prepared.

ROUTE OF THE ROAD.

This road, when completed, will connect the cities of Memphis and Knoxville, in Tennessee, by the shortest and most practicable route, passing through Somerville, Bolivar, Columbia, McMinnville and Kingston. On leaving Memphis, it is located on the table-land between Wolf River and Noncomah Creek, on Wolf and Soosahatchie Rivers, and bisects the angle formed by the Memphis & Louisville and Memphis & Charleston Roads. The surface of the country is undulating,—in places rolling and broken, but with no serious obstacles to the construction of a first-class road at the average cost per mile of Southern roads. The road has been located as far as Bolivar; and with the view of bringing its cost as nearly as possible within the means of the people along the line, the Directory has adopted a gauge of 3 ft. It has not been found necessary to use a steeper gradient than 66 ft. per mile,—and this only for short distances. There are no curves of less than 1,146 ft. radius, and none of this radius on steeper grades than 46 ft. per mile.

THE ROAD-BED.

Clearing and Grubbing, where there is any, is heavy; as the timbered land is covered with a dense growth of white oak, poplar, gum, and hickory of the finest quality.

The Grading will be all earthwork and easy to handle, as there is neither hard-pan, loose rock, nor solid rock found on this portion of the line. The average haul will not exceed 400 ft.

Bridging.—There will be one girder-bridge, of three 50 ft. spans, over Wolf River. The piers will be piling.

Piling and Trestling and Log Culverts.—In consequence of the soil on parts of the line being very liable to wash during heavy rains, piling will generally be used in preference to trestling,—for which safe foundations would in some places be difficult to obtain. The unusually large quantity of piling is not attributable to the crossing of numerous watercourses, or low and swampy lands; but to the fact that there is no rock suitable for building purposes found in any of the western counties of Tennessee, and, consequently, it is deemed more economical to use piling where culverts are requisite. Sufficient room will be left for putting in masonry after the road is in operation,—inasmuch as building-stone, hydraulic cement and lime of excellent quality can be obtained, and hauled on cars from the splendid quarries through which the road will pass near its crossing of the Tennessee River, to the site of the structure.

Prices.—The costs of materials and labor are such as are now ruling in this section, and are fair and reasonable.

Engineering.—This, with right of way, salaries, printing, stationery, etc., will cost as much on the narrow as on the broad gauge; at least such is my experience with the surveys.

SUPERSTRUCTURE.

The average weight of rail per yard on Southern roads is about 60 lbs., and of engines about 25 tons. As it is not intended to run engines of greater weight than 15 tons over the Memphis & Knoxville Road, I have estimated the rails at 30 lbs. per yard, which I think will be a fair comparative estimate. With the view of contributing a few facts with regard to the comparative cost of broad-gauge and narrow-gauge railways in West Tennessee, I herewith submit the estimates in detail, so as to show the comparison of each particular kind of work, or material used. The saving in favor of the 3 ft. "narrow-gauge" is very great, amounting to $227,136.00 for 30 miles of road-bed and superstructure. There will doubtless be some saving in the cost of rolling-stock and equipments; but as this is controlled more by the amount of traffic the road has to perform, than by the gauge, I have not estimated it. Had this line been through a mountainous country, with heavy rock-excavations, the narrow gauge would have effected a much greater saving than that above stated, which though for a comparatively level country amounts to 41 per cent.

Estimate of Cost of the First Division, Extending from Memphis to Macon, Length Thirty Miles, Gauge Five Feet.

COST OF ROAD-BED.

664	Stations, clearing and grubbing at $9.00 per Station		$5,976 00	
461,150	Cubic yards earth excavation at 30 cents per cubic yard		138,345 00	
150	Lineal feet girder bridge at $12 per Lineal foot		1,800 00	
5,665	Lineal feet piling and trestling at $7 50 per Lineal foot		42,412 50	
41,520	Cubic feet timber in log culverts at 3½ cents per cubic foot		1,453 20	
36,950	Cubic feet timber in cattle-guards, roads, etc., at 3 cents per cubic foot		1,108 50	
9,860	Feet board measure, plank in ditto, at 3 cents per foot, board measure		295 80	
	Laying thirty miles of track at $500 per mile		15,000 00	
			$206,391 00	
79,200	Cross-ties at 40 cents each	$31,680 00		
	Engineering, right of way, salaries, office expenses, stationery, incidentals	10,000 00		
			$41,680 00	
				$248,071 00

COST OF SUPERSTRUCTURE.

3,168	Tons of Rails (60 lbs. per yard) at $90.00 per ton	$285,120 00	
12,000	Joint fastenings at $1 each	12,000 00	
165,000	Pounds spikes at 5 cents per pound	8,250 00	
			$305,370 00
	Total for road-bed and superstructure		$553,441 00
	Cost per mile for road-bed		$8,269 00
	Cost per mile for superstructure		10,179 00
	Cost per mile for road-bed and superstructure		$18,448 00

Estimate of Cost of the First Division, Extending from Memphis to Macon, Length Thirty Miles, Gauge Three Feet.

COST OF ROAD-BED.

589	Stations, clearing and grubbing, at $9.00 per Station		$5,301 00	
244,200	Cubic yards earth excavation, at 30 cents per cubic yard		73,260 00	
150	Lineal feet girder bridge at $12 per Lineal foot		1,800 00	
5,655	Lineal feet piling and trestling at $6 per Lineal foot		33,930 00	
29,580	Cubic feet timber in log culverts at 33 cents per cubic foot		887 40	
23 400	Cubic feet timber in cattle-guards and road crossings at 3 cents per cubic foot		702 00	
6,620	Feet board measure, plank in ditto at 3 cents per foot, board measure		198 60	
	Laying thirty miles of track at $375 per mile		11,250 00	
			$127,329 00	
79,200	Cross-ties at 30 cents each	$23,760		
	Engineering, right of way, salaries, office expenses, stationery and incidentals	10,000		
			$33,760 00	
				$161,089 00

COST OF SUPERSTRUCTURE.

1,584	Tons of Rails (30 lbs. per yard) at $95 per ton	$150,480 00	
10,500	Joint fastenings at 80 cents each	8,400 00	
105,600	Pounds spikes at 6 cents per lb.	6,336,00	
			$165,216 00
	Total for road-bed and superstructure		$326,305 00
	Cost per mile for road-bed		$5,369 63
	Cost per mile for superstructure		5,507 20
	Total cost per mile for road-bed and superstructure		$10,876 83

RECAPITULATION.

Distance.	Gauge.	Cost of preparing road-bed for rails.	Cost of superstructure.	Cost of road-bed and superstructure.
Miles.	Feet.			
30	5	$248,071 00	$305,370 00	$553,441 00
30	3	161,089 00	165,216 00	326,305 00
Diff. in favor of 3 ft. ga'e.		$86,982 00	$140,154 00	$227,136 00

COST PER MILE.

	Road-bed.	Superstructure.	Total.
5 ft.	$8,269 00	$10,179 00	$18,448 00
3 ft.	5,369 63	5,507 20	10,876 83
Diff. of cost per mile in favor of 3 ft. gauge.	$2,899 37	$4,671 80	$7,571 17

By adopting the 3 ft. gauge the Company will save on the cost of preparing the road-bed 35 per cent.; on the cost of superstructure 46 per cent.; on road-bed and superstructure 41 per cent.

FINANCES AND BUSINESS RESULTS.

A fair estimate of the cost of building and equipping the First Division of the Memphis & Knoxville Railway on 5 ft. gauge would be $25,000 per mile, which would give for

Thirty miles	$750,000
The amount of Stock Subscriptions which can be raised along the line will not exceed $8,000 per mile, which for 30 miles is.	$240,000
Leaving to be raised by bonds, or otherwise	$510,000
To which should be added, say 15 per cent. discount and commission	76,500
Making total to be raised by sale of bonds	$586,500
Add interest at 8 per cent. for say 20 years	938,400
To be paid in 20 years	$1,524,900
A fair estimate for same division in the 3 ft. narrow gauge would be $13,000 per mile, or	390,000
Stock subscriptions as above	240,000
Leaving to be raised by bonds, or otherwise	$150,000
To which add 15 per cent. discount, commissions, etc	22,500
Making the total to be raised by sale of bonds	$172,500
To which add interest at 8 per cent. for 20 years	276,000
To be paid in 20 years	$448,500
To be paid by the broad or 5 ft. gauge,	$1,524,900
To be paid by the narrow or 3 ft. gauge	448,500
Saved by using the narrow gauge	$1,076,460

In 20 years, $53,820 per annum.

WHAT THE ROAD CAN DO.

Suppose the gross earnings of the road on either gauge to amount to $5,000 per mile, per annum, the saving on first cost would enable the narrow-gauge road to transact the same amount of business for 5½ per cent. less than it could be transacted for by the broad-gauge. In other words, the Memphis & Knoxville Railway, built on the narrow gauge, will be able to pay the same rate of interest on its bonds, and the same dividend on its capital stock, and then, by reason of its *reduced cost of construction alone*, carry freight and passengers for 5½ per cent. less than could possibly be done by the broad gauge over the same route.

In addition, there will doubtless be a large saving in the expense of operating the narrow-gauge road, but of this I am not able to speak from experience.

Respectfully submitted.

THOS. H. MILLINGTON,
Chief Engineer.

Mr. Edmund Wragge, Chief Engineer of the Toronto, Grey & Bruce and Toronto & Nipissing Narrow-Gauge (3 ft. 6 in.) of Canada, has made a report to the Chairman

of the National Central Narrow-Gauge Committee, Hon. C. H. Howland, of St. Louis, as follows:

TORONTO, GREY & BRUCE.

Cash cost, Weston Junction to Orangeville, 41 miles.

	Total.	Per mile.
Grading, fencing, ties, bridges and culverts	$196,595	$4,795
Rails and fastenings	181,015	4,415
Track-laying and ballasting	67,770	1,653
Station buildings	24,407	595
Right of way	24,600	600
Telegraph	1,640	40
Engineering	23,370	570
Commissions, officer, Directors' fees, etc.	15,469	377
Law expenses	3,936	96
Sundries	2,000	49
	540,802	$13,190
Rolling stock	105,960	2,560
Total cost	$646,762	$15,750

The Toronto, Grey & Bruce Railway has cost in cash, as per detailed estimate annexed, $13,190 per mile, exclusive of rolling-stock; and including rolling-stock $15,750 per mile between Weston Junction and Orangeville (the portion of the road which is entirely completed). The earthwork averages 10,500 cubic yards per mile. The line is fenced throughout, at a cost of $800 per mile. The grubbing amounts to an average of one-half an acre per mile; the clearing to three acres per mile; slashing on each side of the railway to the extent of four acres per mile has also been done, the grubbing, clearing and slashing having together cost $140 per mile. The ties have cost on this section an average of 25 cents each, or $500 per mile.

TORONTO & NIPISSING.

Cash cost, Scarboro' Junction to Uxbridge, 32 miles.

	Total.	Per mile.
Grading, fencing, ties, bridges and culverts	$151,307	$4,725
Rails and fastenings	139,041	4,345
Track-laying and ballasting	46,696	1,460
Station buildings	15,012	470
Right of way	22,092	690
Telegraph	1,500	47
Engineering	14,110	441
Commissions, officer and Directors' fees	10,292	321
Law expenses	936	30
Sundries	615	20
	$401,601	$12,549
Rolling stock	101,588	3,175
Total cost	$503,289	$15,724

The Toronto & Nipissing Railway, from Scarboro' Junction to Uxbridge, has cost in cash the sum of $12,549 per mile, exclusive of rolling-stock, or including rolling-stock, $15,724 per mile. The earthwork has averaged 9,750 cubic yards per mile. The line is fenced throughout at a cost of $700 per mile. The ties have cost $480 per mile on this section, and the grubbing, clearing and slashing, $140 per mile.

EDMUND WRAGGE,
Chief Engineer.

THE CENTRE RAIL SYSTEM.

From "Engineering."

The centre rail system, first proposed and patented by Mr. Vignoles, practically tested some two and twenty years ago by Mr. George E. Sellers, on the Panama Railway, and more recently so strongly advocated by Mr. Fell, is about to have another trial under auspices far more favorable than those which attended its employment on the late Mont Cenis Railway. This time the trial is to be made in Brazil, on the Cantagallo Railway, a line which bids fair to occupy an important place among the engineering works which have done, and are doing, so much to develop the resources of the Brazilian empire. At the present time the important coffee-producing district of Cantagallo, situated at a high level, and separated from the lowlands by the Organ mountains, has to transport its produce by mules across the mountain roads to Caxoeira, from which place a railway of 5 ft. 3 in. gauge has for some thirteen years past extended to Rio Janeiro. This transportation by mules, however, being costly and uncertain, naturally led to a desire to extend the railway communication across the Organ range into the heart of the Cantagallo district, and ultimately Dr. Bernardo

Clemente Pinto, an enterprising contractor, obtained from the Brazilian Government a concession for the construction of a line from Caxoeira, across the mountain passes to Nova Friburgo, this railway to be ultimately extended 60 miles further to the city of Cantagallo. This line, now being constructed by Dr. Pinto, has a gauge identical with that of the Mont Cenis Railway, namely, 1.1 metres or 3 ft. $7\frac{5}{8}$ in., and that part of it which traverses the coast side of the mountains, will be laid with the centre rail. In a length of $7\frac{3}{4}$ miles, this mountain portion of the line rises about 3,000 ft., the gradient varying from 1 in 20 to 1 in 12 and being for the greater part of the length 1 in 13, while the curves are of 40 metres, or about 140 ft. radius. In descending from the summit level on the Cantagallo side, the mid-rail is dispensed with, the gradients over the 12 miles extending to Nova Friburgo being easy.

The permanent way of the mountain portion of the Cantagallo line is identical in construction with that of the Mont Cenis Railway as designed by Mr. Brunlees. The rails weigh 65 lbs. per yard, the central rail being raised 9 in. above the ordinary carrying rails, and being bolted to wrought iron chairs, which are in their turn secured to a longitudinal sleeper fixed to the ordinary transverse sleepers. As in the case of the Mont Cenis Railway also, the mid-rail will, on the Cantagallo line, only be laid on the steep inclines, the ends of each length being tapered so that the gripping wheels may pass on and off easily.

For working the portion of the line thus laid with the mid-rail three locomotives have been ordered from Messrs. Manning, Wardle & Co., Leeds, and the trial of one of these engines took place on June 21st and 22d last. It was made on a temporary line about half a mile in length, laid for the purpose on the abandoned wire-rope incline which formerly formed part of the Pickering and Malton branch of the North-Eastern Railway. The old incline was 1 in 14, but by the construction of a slight embankment at the upper end the gradient of the experimental line has been increased at that part to 1 in 11, while a very sharp **S** curve has been introduced. It was intended that the radius of these curves should be the same as that of the curves on the Cantagallo line, namely, 40 metres, but by some mistake they were made much sharper, and the actual radius is, we believe, but about 26 metres, or, say, about 85 ft. The line—which has been put down by Mr. Baines, the district superintendent of permanent way, under the directions of Mr. Charles Cabry, the Company's resident engineer—is exceedingly well laid, and was in thorough good order when the experiments were carried out.

The engine is carried on two pairs of coupled wheels 2 ft. 4 in. in diameter, these wheels being driven by a pair of outside cylinders 13 in. in diameter with a stroke of 14 in., while a second pair of cylinders, 14 in. in diameter and 12 in. stroke, drive the two pairs of horizontal gripping wheels 1 ft. 10 in. in diameter. The wheel base of the engine is 7 ft., while the two pairs of horizontal gripping wheels are placed as close together as possible, and are situated midway between the axles of the vertical wheels. The pair of cylinders by which the horizontal wheels are driven are arranged on the centre line of the engine one above the other, the piston rod of each cylinder being attached to a long transverse crosshead suitably guided, from the ends of which connecting-rods lead off to cranks on the axes of the leading horizontal wheels. The axis of each horizontal wheel has two cranks at right angles to each other, the two axes on each side of the centre rails being connected by coupling rods, while the leading axis of each pair so coupled is driven by the connecting-rods already mentioned.

The axes of the horizontal wheels are mounted in bearings carried by cast-steel cradles so arranged that by means of a right and left-handed screw the gripping wheels can be made to exert a pressure of any desired amount up to 40 tons on the mid-rail. The engines for driving the horizontal and vertical wheels are perfectly independent of each other, there being two regulators and two sets of reversing gear, while there are also independent ordinary and mid-rail brakes. The engine has 772 sq. ft. of total heating surface, and is provided with a pair of wing tanks carrying 520 gallons of water, while the weight is 25 tons empty, or about 30 or 31 tons in working order.

The diameter of the vertical wheels being 28 in., while the cylinders driving them are 13 in. in diameter, with 14 in. stroke, it follows that these cylinders are capable of exerting a tractive force of 84.5 lbs. for each pound of effective pressure per sq. in. on the pistons. On the other hand, the inside cylinders being 14 in. in diameter by 12 in.

stroke, and driving 22 in. gripping wheels, each pound of effective pressure per sq. in. on their pistons is equivalent to a tractive force of 106.9 lbs. This tractive force is greater than that capable of being exerted by the outside cylinders in the proportion of 5 to 4 very nearly, and it is possible that this proportion may have been decided upon in view of the fact that the pressure which it is possible to exert upon the horizontal wheels is greater than that exerted by the vertical wheels on the rails. However this may be, the engine appears to us to be deficient in cylinder power, and it is certain that, as matters stand, the outside cylinders are not capable of using up the adhesion of the vertical wheels unless the engine be worked at a much higher pressure of steam than is at present intended. With a clean rail, the adhesion may certainly be reckoned at 6 tons at least—while in many cases it would be much more—and to utilize this adhesion would require a mean effective pressure on the pistons of the outside cylinders of nearly 160 lbs. per sq. in., corresponding to, say, 190 or 200 lbs. in the boiler, while at present the usual boiler pressure is but 130 lbs. per sq. in.

Messrs. Manning, Wardle, and Co. are not responsible for the proportions of cylinders adopted, although the general design and details of the engines have been worked out by them. They have had much experience in the designing of locomotives for special circumstances, while the high character of the workmanship which they turn out is well known, and in the case of the Cantagallo locomotives they have, both as designers and constructors, performed their duties admirably. In the case of the Mont Cenis Railway many of the breakdowns which occurred were indubitably due to the defective design and workmanship of the engines employed, and hence there was some difficulty in separating the failures due to these causes from those due to the mid-rail system *per se*. In the case of the Cantagallo line, however, the mid-rail system will certainly have a fair trial, and the breakdowns, if they do occur, cannot be laid to the charge of the locomotive builders. Doubtless, Messrs. Manning, Wardle, and Co. have done the best which is to be done for the centre rail system, and although they have produced a locomotive which, from its complication, can only be admire as a specimen of workmanship, the complication has been reduced to the least amount compatible with the system on which the engine is constructed. The trials were carried out in the presence of Mr. James Brunlees, Mr. Fletcher, the locomotive superintendent of the North-Eastern Railway, Mr. R. F. Fairlie, Mr. Hemans, Mr. Barnes, late the locomotive superintendent of the Mont Cenis Railway, Mr. Rowland Cox, Mr. William Dredge, Mr. Manning, Mr. Wardle, Mr. J. B. Fell, and a number of other engineers.

For the purpose of testing the hauling powers of the engine there had been brought to the incline four of the wagons made for the Cantagallo line by the Railway Carriage Company, of Oldbury. These wagons, of which the weights vary from 4 tons 8 cwt. to 4 tons 8 cwt. 2 qr., are each carried on six wheels, arranged on Mr. John Clark's system, the central pair being capable of shifting laterally, and being connected to the end axles in such a manner as to cause them to assume a radial position when the wagon is traversing a curve. Each wagon is fitted with both ordinary and mid-rail brakes, and during the experiments each was loaded with 6 tons of railway chairs.

The first run was made with two wagons, these carrying besides the load above mentioned, about 1¼ tons of passengers, thus making a load hauled of about 22 tons 6 cwt., or, including the engine, a gross weight of about 52½ tons. Both the inside and outside cylinders were used, and with this load the engine ascended the incline without any difficulty at a speed of 10 or 12 miles per hour, the curves at the upper and steepest part of the incline, however, not being traversed. As the load on this occasion was considerably below the tractive power of the engine, we need not speak of this trial further.

In the second trial the load was increased by the addition of two other wagons, making the train load, exclusive of passengers, 41 tons 12 cwt. 3 qr. On this occasion 28 passengers were carried, so that the train load may be taken as 43½ tons, exclusive of the engine, or, say, 73½ tons in all. This load was also taken up steadily at a speed of about 8 miles per hour, and although the engine was stopped close to the first curve near the summit, at a point where only the engine, and perhaps the leading wheels of the first wagon, stood on the incline of 1 in 11, yet there is no doubt that the engine would have taken the load right up the latter gradient had the curves

been such as to render it advisable for the experiment to be made. As it was, however, the curves were, as we have already explained, made too sharp, and, except in the third experiment, of which we shall speak directly, it was not deemed advisable to run round them. The steepest part of the incline over which the whole of the above load was drawn was 1 in 12, and if we take the frictional resistances of the engine at 40 lbs. per ton (and a subsequent experiment showed that with the two sets of machinery working, this is a very moderate allowance), and that of the wagons at 8 lbs. per ton, we get the total resistances as follows:

	lbs.
Gravity $= \frac{73.5 \times 2240}{12} =$	13,720
Engine friction = 30 tons at 40 lbs. = ...	1,200
Wagon friction = 43¼ tons at 8 lbs. = ...	348
	15,268

The resistance thus amounted to about 6¾ tons, or little more than one-fifth the weight of the engine, and without doubt if sufficient outside cylinder power were available the engine would, in favorable weather, have taken up the above load without the use of the gripping wheels at all, while, even under less favorable circumstances, the use of sand would secure the requisite adhesion. It has been stated that the proportions of the cylinders are such that the inside cylinders exert a pull of 106.9 lbs., and the outside cylinders a pull of 84.5 lbs. for each pound of effective pressure per sq. in. on the pistons. Supposing, then, that equal effective pressures are maintained in the two sets of cylinders, the mean effective pressure requisite to exert the tractive force of 15,268 lbs. would be 80 lbs. nearly, a mean effective pressure well within that obtainable with the boiler pressure at which the engine is usually worked.

The length of the incline was not sufficiently great to fairly test the steaming capabilities of the engine, but, so far as could be judged from the experiments, there was no sign of any deficiency in this respect.

The third and fourth experiments were made to test the hauling power of the engine when not employing the central rail, and were of an interesting character. In the third experiment the load attached to the engine consisted of one wagon only, the weight hauled, including the passengers carried, being about 12 tons, making the gross load, including the engine, 42 tons. With this load the engine ascended readily to the very top of the incline, traversing the **S** curves of 85 ft. radius, situated on the gradient of 1 in 11, and showing no signs of slipping during any part of the run. Inasmuch as during this trial the horizontal wheels were out of contact with the mid-rail, the engine friction may probably be taken as 15 lbs. per ton; and if the wagon friction be taken as 8 lbs. per ton, as before, the resistances, when traversing the upper part of the incline during the third trial, will be as follows, exclusive of any allowance for the additional friction on the curves:

	lbs.
Gravity $= \frac{42 \times 2240}{11} =$	8553
Engine friction = 30 tons at 15 lbs. = ...	450
Wagon friction = 12 tons at 8 lbs. = ...	96
	9099

or about 4¼ tons, a resistance requiring an adhesion of only about $\frac{1}{7}$ the weight of the engine. Owing to the small size of the outside cylinders, however, the exertion of the tractive force just mentioned required a mean effective pressure of 107.7 lbs. per sq. in. on the pistons; and to get this it was necessary to raise the boiler pressure to nearly 140 lbs.

The fourth trial was, like the last, made without the use of the horizontal gripping wheels, but the load was increased by the addition of a second wagon, making the load hauled, including passengers, 22½ tons, and the total weight, including engine, 52½ tons. To obtain the necessary pressure in the cylinders the boiler pressure was increased to 145 lbs., and under these circumstances the load was taken up readily. Owing to a misunderstanding, however, sand was applied to the rails during a portion of the run, not on account of any signs of slipping being apparent, but from a desire on the part of the driver to make "assurance doubly sure." It is much to be regretted that sand was thus unnecessarily applied, as the adhesion required was certainly well within the amount available with an unsanded rail. As in the case of the first and second trials, the engine was stopped just below the curves at the upper end of the incline, and the whole load may therefore be taken as having been hauled over a gradient of 1 in 12, giving the resistance as follows:

	lbs.
Gravity $= \frac{52.5 \times 2240}{12} =$	9,800
Engine friction = 30 tons at 15 lbs. = ...	450
Wagon friction = 22½ tons at 8 lbs. = ...	180
	10,430

corresponding to a mean effective pressure of $\frac{10,430}{84\ 5} = 123.4$ lbs. per sq. in. on the pistons. Had greater cylinder power been available the engine would undoubtedly have taken a much heavier load up the incline without the use of the horizontal gripping wheels.

The next experiments were made to test the tractive power of the engine when employing the inside cylinders only, and it is only fair to state that they were made under some disadvantages. It is at all times difficult to keep the oil thrown off by the machinery for working the horizontal wheels clear of the mid-rail, and in their trials after the incline had been traversed by the engine several times at brief intervals, the mid-rail had got very greasy for short lengths in several places, and the oil thus thrown upon it had had no time to harden or dry up. The consequence was that to obtain the necessary adhesion during the two experiments of which we are about to speak, the gripping wheels had to be forced against the mid-rail with a much greater force than would have been necessary had that rail been in fair condition, and hence the frictional resistances of the engine were materially increased. It has also to be borne in mind that during the fifth and sixth experiments the machinery of the vertical wheels had to be driven, whereas when the trials were made with the outside cylinders only, the machinery belonging to the horizontal wheels was at rest.

In the fifth trial the load of the engine consisted of one wagon only; but as this load was considerably below the power of the engine we need not discuss it further. In the sixth trial, however, two wagons were attached, the load being thus the same as during the fourth trial. As soon as the train was fairly on the incline, and the engine had got past that portion of the mid-rail which was in the most greasy state, steam was shut off from the outside cylinders, and the horizontal gripping wheels left to do the work alone. No index for showing the pressure had been affixed to the screw for tightening up the gripping wheels, but the pressure applied to the mid-rail was estimated at 40 tons. Notwithstanding this, however, the horizontal wheels slipped from time to time as they came upon a greasy place on the mid-rail, and had to be assisted by admitting steam to the outside cylinders.

A most important point proved by this experiment was the great increase of engine friction due to the employment of the mid-rail machinery. The load being the same as during the fourth experiment, the resistance, with the exception of that portion due to engine friction, would also be the same, while owing to the fact of the cylinder power of the inside engines being greater than that of the outside engines in proportion of 5 to 4, the mean effective pressure required on the pistons should have been less than during the fourth experiment. In reality, however, it was found that to draw the load the same boiler pressure was requisite in the sixth trial as in the fourth, and the mean effective pressure seems to have been about equal in the two cases. To what an excessive proportion of engine friction this state of affairs corresponds, a simple calculation will prove. In the case of the fourth experiment, the resistance to be overcome corresponded to a mean effective cylinder pressure of about 123½ lbs. per sq. in., and this mean effective pressure was obtained with a boiler pressure during the sixth experiment being also 145 lbs., the mean effective pressure in the inside cylinders did not differ greatly from the 123½ lbs. just mentioned; and as each pound of effective pressure per sq. in. on the inside pistons gives a tractive force of 106.9 lbs., the pull exerted during the sixth experiment is approximately $106.9 \times 123.5 = 13,202$ lbs. Of this force 9800 lbs. is accounted for by the resistance due to gravity, and 180 lbs. by the friction of the wagons, leaving $13,202 - (9800 + 180) = 3222$ lbs. to be accounted for by engine friction, or over 100 lbs. per ton for the actual weight of the engine; the pressure exerted on the mid-rail may be fairly regarded as equivalent to engine weight, and as in this case this pressure amounted to 40 tons, the engine friction might be expected to equal that of a $40 + 30 = 70$ ton locomotive. Even regarded in this way, however, the friction is excessive, amounting to $\frac{3220}{70} = 46$ lbs. per ton, an amount far in excess of that allowed in

calculating the resistances encountered during the second trial. The mode of comparison adopted, of course, does not admit of any very minute accuracy, but the results obtained by it are sufficiently decisive to show that the working of the mid-rail machinery is attended with a most disproportionate amount of friction.

During the various experiments a number of trials were made of the brake arrangements, and it was found that in all cases, whether ascending or descending, the trains were under most complete control. The engine was driven during the experiments by Mr. Thomas Morton, late the assistant superintendent on the Mont Cenis line, and who is going out as locomotive superintendent on the Cantagallo Railway, where he will have the assistance of Mr. Henry Mason, one of the first engine drivers on the Mont Cenis. Altogether, the centre-rail system will be tried in Brazil under the most favorable auspices. The experience gained on the Mont Cenis has been turned to account in constructing the new line and designing the stock; the makers of the locomotives, Messrs. Manning, Wardle and Co., have done everything that careful designing and first-class workmanship could do to render the engines a success, and, in fact, Mr. Fell could scarcely desire a fairer trial for the system he advocates than it is about to receive in the passes of the Organ mountains. That the mid-rail affords a mode of surmounting inclines with loads which could not be taken up by an ordinary engine, is, of course, a self-evident matter; but that it forms the best—or even approximately the best—mode of scaling mountain inclines, is doubtful.

FURTHER NOTES ON THE CAISSONS OF THE EAST RIVER BRIDGE.*

By F. COLLINGWOND, C. E.

A paper read before this Society at the last annual Convention, entitled "A Few Facts about the Caissons of the East River Bridge,"† gives account of the construction and sinking of the Brooklyn caisson; these Notes refer almost entirely to the New York caisson.

CONSTRUCTION.

Preliminary borings on the sites of the piers of this Bridge, disclosed the fact that the river bed and underlying strata on the Brooklyn side were essentially different from those on this, the New York side. There, at a depth of about 45 ft., a uniformly hard bottom was reached, which was entirely satisfactory as a foundation. Here, on the contrary, the strata were exceedingly irregular, all more or less yielding, and with extensive beds of quicksand reaching nearly to the rock, which was found at a depth of from 77 ft. to 92 ft. below high tide.

It was at once decided, therefore, that the foundation must go nearly if not quite to the rock. To provide for the pressure of a larger mass of masonry, compared with that of the Brooklyn pier, it was deemed advisable to increase the size of the caisson, and it was made 102 by 172 ft.; the air-chamber was of the same height as in the other caisson, 9 ft. 6 in. The cross-frames, for the support of the central part of the roof were much heavier, being of solid timber, 4 ft. thick; and additional bearing surface on the quicksand was obtained by the introduction of minor frames both across and lengthwise of the caisson. The total sustaining surface, when all brought to a bearing, was about 2,700 ft., or fully twice that of the Brooklyn caisson. This, it was thought, was required to guard against the dangerous settlement that might occur should there be a sudden escape of air from the air-chamber, which previous experience had shown to be quite possible.

The roof was increased in thickness from 15 to 22 ft., and a coffer-dam built from the top of the twelfth roof course to high-water mark. By this means greater buoyancy was obtained, the pressure on the frames and other parts during sinking, lessened, and the stability materially increased.

LEAKAGE OF AIR.

The interior of the air-chamber was lined throughout with light boiler iron riveted together, and caulked. The surface covered by the lining had an area of about

* A paper read before the American Society of Civil Engineers.

† No. XXX. Transactions.

26,000 sq. ft., and was pierced by 6,000 bolts. Although great pains were taken to make these tight, it was found after launching, that four compressors were required to overcome the leakage of air. Men were sent down, and, floating around on rafts, they succeeded in stopping the leaks, so that one compressor at half speed, and throwing about 90 ft. of air per minute, more than overcame the loss.

When the pressure was 34 lbs. above the atmosphere, with the shoe sealed by water, the leakage was about three times as great. With the shoe uncovered, the escape of air underneath it and upward throug the sand, was frequently 1,200 to 1,500 ft. per minute, requiring nearly the whole compressor force to supply it. This could always be partially controlled by banking up inside the shoe with earth.

THE AIR SUPPLY

was furnished by 13 compressors, throwing 3 cubic feet of air (normal pressure) per revolution. These were seldom all running at once; at the greatest pressure the number varied from 8 to 12, with a speed of 30 to 80 revolutions per minute. The highest limit was of course reached, when the sand siphons were throwing out material. In the compressor room a mercurial gauge showed the actual pressure, and, close by it, an indicator moved up and down with the tide, and traversed a strip of paper, on which were marked pounds. The paper being adjusted each morning, the engineer had always before him the real and the required pressure. At the beginning of the sinking, the pressure was kept fully up to that required to balance the water pressure at the shoe.

After a few feet of excavation, it was found that a $\frac{1}{2}$ lb. less pressure was sufficient to keep the water out. At 20 ft. of excavation, or a total depth of 57 feet, we began to run regularly with 1 lb. less. The material, down to this depth, was sand and gravel, but it evidently offered a sensible resistance to the passage of water through it. When the pressure was run down by the excessive use of the sand siphons, the water would run in slowly for an hour or two; the pressure had then to be put up to the highest safe limit, and held there two or three hours, to drive the water out.

THE WATER SHAFTS.

One inconvenience arising from this, was the difficulty in keeping a safe supply of water in the pools around the water shafts. The natural effect of the air pressure would be to force the water deeper down in the centre of the chamber (where the shafts were) than at the shoe; hence there was—as proved by currents in the trenches—a constant loss by drainage from the shafts to the chambers in addition to that caused by the dredge buckets. The head of water in the city mains being too small to keep up the supply,—as a precautionary measure, a steam pump was connected with the caisson water pipes, which prevented further trouble from this cause.

The water shafts projected 2 ft. below the shoe, and the water was always kept in the pools a foot above the bottom of the shafts, and ordinarily much higher. This was necessary to provide against sudden fluctuations in pressure, and on account of the pulsations caused by the plunging in or withdrawing of the buckets.

The sand in the pools always stood at a very low angle, hence they were kept large and well dug out. Unless this precaution were taken, the shafts were liable to be dangerously sealed, when the work was stopped by the slow deposit of earthy matter, held in suspension by the water while dredging was being done.

As to be expected, the shafts were most useful during the early part of the work, in removing mud and other materials which could not be taken out by the sand siphons. They were employed, however, until a depth of 74 ft. was reached, where they became practically useless, for the reason that, in lifting through such a depth of water, nearly all the material was washed out of the buckets.

CAISSON LEVEL.

Before the caisson was put in place, the river bottom, at a depth of 37 ft., was dredged to as nearly a uniform level as possible. The scour that took place under the outer edge of the caisson before it was firmly grounded, caused it to take the bottom at low tide, fully 2 ft. out of level. To prevent this, earth was thrown in at high tide, and a tolerably uniform bearing obtained.

At one time afterward, before all the dock logs and similar obstacles had been cleared from under the frames, the caisson was 9 in. out of level at the corners; but after getting well into the sand, and while

settling from 6 to 11 in. per day, the greatest difference of level was 6 in.; and at times for a whole week it would not be out more than 1 or 2 in. Towards the end of the excavation, fully one-half of the caisson rested on quicksand, and the other half on cemented gravel; but even under these extreme circumstances we were able to put the hard side down lower, while the soft side remained stationary.

Mr. Collingwood said: To show how readily the level was controlled, I will state: we stopped the caisson exactly at 78 ft., and the difference of level at the extreme corners of the coffer-dam was only an inch, and of the masonry only ¾ in. We stopped and held it there without difficulty.

SIDE FRICTION.

The excess in weight of masonry, timber, and other parts over the lifting force of the air, varied from about 500 tons to 20,000 tons, the latter being the extreme amount at low tide, when the pressure had been allowed to run 5 lbs. below that due to the head of water, and the caisson was at its greatest depth. It was found impracticable to determine the side friction with accuracy, for the reason that at no time were the frames and shoe entirely unsupported. Two different observations gave about 400 lbs. per sq. ft.; towards the close, when the material was compacted more firmly against the caisson from the slowness of its settlement, the side friction was evidently much greater—probably between 500 and 600 lbs. per sq. ft. To increase the weight, a considerable portion of the sand blown out was allowed to remain inside the coffer-dam.

Notwithstanding the large overweight on the caisson (above its buoyancy when inflated), the roof was scarcely changed in form; the depression, as shown by levels, being about an inch;—an admirable test of the thoroughness of the bolting. No blocking was used under the frames, as on the Brooklyn side; they rested directly on the sand.

FOUNDATION.

When within about 10 ft. of the highest portion of the bed-rock, a complete series of soundings was made over the bottom. These revealed a stratum of cemented gravel over the entire area, at a depth of from 77 to 80 ft., and above and below this a great number of boulders, many of them of large size.

This was the first stratum reached which was of suitable material to sustain the pier, and bore certain evidences of not having been disturbed. For instance, at 62 ft. a bone of the domestic sheep was found in the sand under a large boulder; and still lower down, fragments of brick and pottery.

The settlement of the Brooklyn pier on a similar foundation, with two-thirds of the full load upon it, had been but three-eighths of an inch; therefore it was decided to stop excavation at the depth of 78 ft. For about 60 ft. on one side, the bed rock was struck at 77 ft.; this was blasted out a foot below the shoe, and the space filled in with earth. At two corners a small depth of quicksand remained above the hard stratum; this was removed, and concrete put in its place.

The filling was done as in the other caisson, except that the greater supporting power of the frames rendered the brick piers superfluous, and they were dispensed with. In filling, the spaces under the frames were first made solid; then, wherever there was quicksand under the shoe, a trench was cut out down to the gravel layer mentioned, and filled with concrete. After this the filling proceeded by sections, and bulkheads were put up for the purpose, as described in the paper before mentioned.

While sinking the last 8 ft., all the stones found, except the small ones (which were removed in the usual manner), were stowed in pockets attached to the frames, or piled near the centre of the chambers, in spaces excavated for the purpose.

The last 2 ft. of excavation consisted mostly of trenching; and as far as practicable, the earth was heaped up and not removed, by which means a large amount of concreting was saved, and the expense of filling lessened.

SAND SIPHONS

have been mentioned frequently, but no description given of them. In designing the caisson, pipes had been carefully located over the whole area of the roof, with the idea of moving the material excavated the least possible distance. The first plan was to use water as the vehicle by which to carry out the sand, and for this reason the pipes were grouped so as to give one of 4 in. to every 3 or 4 of 3.5 in. diameter. These pipes extend vertically through the roof, and sections were added above as the caisson descended.

During the early part of the excavations, the material was such that it had all to be

removed by the dredges. Before it became practicable to employ the siphons, another consideration, namely, ventilation, caused an entire change of plan, and it was decided to use the air of the caisson as the motor. The caisson leaked so little that otherwise, to maintain a proper degree of purity, it was necessary to waste air; and there was no good reason why the power thus stored up should not be utilized. This being decided, the question of interior arrangement came up. We first tried rubber hose lined with spiral springs to prevent collapsing, making the pieces about 5 ft. longer than the chamber was deep, or 14 ft. in length. The hose thus hung from the roof in a curve, and it was thought that, by sweeping it around, all the material within the circle described could be taken out with little or no shovelling.

From the constant jamming of small stones and sand in the bend of the hose, even when mixed with an abundance of water, this method very soon proved impracticable. We next tried an injector, allowing air to enter an adjustable annular space surrounding a central passage for the sand and air, to which pascage a pipe was connected, leading to the bottom of the chamber; this worked tolerably well, but wasted too much air for the work done.

The next step was to shorten the hose, so that it reached within a few inches of the bottom of the caisson. The material was thrown by about six laborers to a point where another laborer kept the lower end of the hose in moderate motion from side to side. This worked very well, but the sand soon wore out the springs, and the hose collapsed.

The final arrangement adopted was as follows: A piece of pipe 2 ft. long was screwed on, near the roof; to this a full way cock of the same size opening was attached, and next a straight piece of pipe extending to within a foot of the bottom of the caisson. The most effective way of working this was to heap the sand and gravel around the lower end of the pipe, for 2 or 3 ft. in depth; then to open the cock wide and let the air carry the material out.

When working at the best in clean sand, a pipe 3.5 in. in diameter, under a pressure of 25 lbs. per sq. in., has thrown out 30 cubic yards in an hour. Owing to the large admixture of gravel with the sand, the stoppages from choking were frequent, and this speed was never reached except experimentally. When the pressure reached 28 lbs., it was found that the 3.5-in. openings allowed too much air to escape, and the pipes were reduced at the lower end to 2.5-in. diameter. This arrangement was all that could be desired, so long as the sand was clean. At the last, however, there was a large admixture of clay with the sand, and we had to remove the reducers, and use fewer siphons.

The sand was very sharp, and our next trouble was, that the pipes wore through near the roof. When this happened, a 3-in. pipe was forced up about 2 ft. into the 3.5-in. pipe remaining in the roof, and a 3-in. cock attached. When this wore off, a second reduction to 2.5 in. was made. A mechanic was on hand at all times to make such repairs as were needed, and to clear the pipes.

Occasionally, two stones would jam in a pipe at some distance up; these were easily removed by forcing up jointed rods from below, or dropping a bar attached to a rope from above. When working at a pipe from below, the precaution was always taken to screw on a cast-iron cap above.

During the first 25 ft. of excavation, it was necessary to throw sand over the sides of the caisson, to keep the piling surrounding it from sinking; the remainder was thrown on the dock and saved for future use. As the pipes leading from the air chamber were vertical, elbows were used to change them to horizontal—an arrangement easily made; but the furious blast of sharp sand cut through in 30 min. the cast-iron elbows at first provided. Wrought iron an inch thick would not stand over 10 hours' use—end wood was bored through as though by an auger.

The plan finally adopted was to use an iron elbow of a foot radius, in which there was an opening on the convex side, in width equal to the interior diameter, and extending within 2 in. of either end; into this a back piece of chilled iron, about 2 in. thick, was fitted and secured by a key driven into 2 lugs cast upon the elbow. It was the work of a few minutes to remove the key and change one of these back pieces; a man was kept on the top of the caisson to attend to this. The device was much cheaper than any other tried, and worked satisfactorily.

Great care was required to prevent accident from the siphons, as with a heavy pressure small pebbles were discharged almost with the velocity of musket balls.

One of the men, by incautious exposure, had a wound made in his arm more than 5 in. long. At the last, when wasting the material inside the coffer-dam, the elbows were all removed, the pipes cut down, and a heavy piece of limestone placed above each, on the coffer-dam braces.

THE TELEGRAPH

used in sending messages up and down was very simple, and worked well. One of the large tubes was capped below, an inch tube (riveted at the joints to prevent slipping) was passed through the cap, and indexes attached. Underneath each index was placed a small horizontal table, on which was distinctly traced a plan of the caisson, together with the position of every pipe and shaft. By the revolution of the small tube, therefore, attention could be called to any one of these in a moment.

A small rod, also, was passed down through the large tube, and its weight balanced by a weight above, attached to a cord passing over a pulley. A small index was fixed both above and below; these traversed vertical boards on which were words and sentences such as, "stop," "start," "bucket is caught," etc., directing what was to be done.

LIGHTS.

In the paper before mentioned I touched upon this subject, and suggested a theory as to the reason why all the lights used (except oxy-hydrogen) smoked so insufferably. The explanation then given was, that the increased tension of the air diminished the freedom of motion of its particles, and that as a consequence of its imperfect circulation about the flame, the carbonic acid and nitrogen set free, surrounded the flame as a film, caused imperfect combustion, and the elimination of large quantities of carbon.

The burners first used in the present caisson were 5 ft., fish-tail, and burned with a flickering yellow light, consuming a great deal of gas, and smoking almost as badly as candles. It seemed to me that if the gas could be forced out in a thin sheet, under considerable pressure, the difficulty might be overcome. Acting on this supposition, I procured burners of various sizes, and also several kinds of pressure regulators. Experiment soon showed that the regulators were, at least for our use, worthless. But to our great satisfaction, on trying a 2 ft. lava tip, of the pattern known as the "excavated bat wing," it burned with a clear white light, and gave off scarcely any smoke. As the depth increased, these also began to smoke; and when at 65 ft. depth, one-foot burners of the same pattern were substituted. No farther trouble was experienced.

The arrangement for gas supply was very simple. An iron tank was fixed in the air-chamber of the caisson, which held about 60 cubic ft. Into this the gas was forced by a force pump, stationed on the dock above; and from it distribution made to the various burners. A water tank above had a pipe leading from it to the bottom of the tank in the caisson. The water column thus formed gave the real measure of the pressure under which the gas was burned. The difference of head (allowing for the difference between salt and fresh water) varied from 2 ft. at extreme high tide, to 9 ft. at extreme low tide; instead of about 2 in. as is ordinarily the case.

VENTILATION.

Soon after the excavation had been started, some peculiar sensations experienced by the workmen, led to the suspicion that an amount of carbonic acid too large for health was present in the air of the chambers. A rough test with lime water showed this to be true.

The question then arose, how much air was required—we were already forcing down more than stated by many authors as necessary to supply a reasonable number of lights, and the men employed; the amounts given varied from 3.5 to 23 cubic ft. per man per min. It apeared at once that these estimates had been made under exceedingly diverse conditions, and afforded no accurate basis for us to work upon.

There seemed, however, to be more uniformity in the published experiments on the amount of air inhaled by each person; so that it was possible to arrive with some accuracy at the actual amount of carbonic acid given off; knowing the amount of gas burned per minute, the carbonic acid from this source also was readily determined. With the total amount of carbonic acid known (having decided on what percentage of vitiation of the air would be allowed), the amount of air required to insure a given degree of purity was found by a simple proportion.

The exhalations from the body are of two kinds: those from the lungs and those from the skin. We will consider first—respiration. Experiments show that a person inhales, when breathing quietly, from 20 to 34 cubic in.; when walking respectively 1, 2, 3, or 4 miles per hour, about 52, 60, 75, or 91 cubic in.; and in working a tread-mill, 107 cubic in. of air—per respiration. The amount of carbonic acid exhaled is equal in bulk to the oxygen consumed, and is about 4.5 per cent. of the air inhaled. Estimating that a laborer in the caisson consumes as much air as a person walking 3 miles per hour, we have with 18 respirations per min., the air breathed by 70 men, 75x70x18= 94,500 cubic in. Of this 4.5 per cent. or 4,252 cubic in. is carbonic acid, exhaled and thrown off by the lungs.

The watery vapor expelled by the system at the pores, is stated to be, by weight, from 1.5 to 2 times the amount of carbonic acid exhaled, and contains carbonic acid, urea, and albuminous substances in a state of decomposition. In the air of the caisson, owing to its nearly constant state of saturation with watery vapor, this vapor would no doubt be given off in the form of "sensible perspiration." In the absence of any data, allow that it contaminates one-quarter as much air as the breath, and we get carbonic acid and the like from the skin equal to $\frac{4252}{4} = 1062$ cubic in.

We come next to the carbonic acid produced by combustion. Carburetted hydrogen consumes in burning, twice its bulk of oxygen; and generates its own bulk of carbonic acid. In other words, a cubic foot consumes 10 cubic ft. of air, and produces a cubic foot of carbonic acid. As we were burning about 5 ft. of gas per min., this gave carbonic acid from the lights equal to 8,640 cubic in., and from all sources as follows:

Breath	4,252	cubic in.
Skin	1,062	"
Gas	8,640	"
Total	13,954	"

or 8.08 cubic ft.

The next thing to determine, was the per cent. of impurity allowable in the air. Pure air contains by volume, in round numbers, .8 nitrogen and .2 oxygen. There is present, also, a small amount of carbonic acid variously estimated from .1 to .04 of one per cent.; "10 per cent. of carbonic acid causes instant death; 5 to 6 per cent. is dangerous to life, and 3 per cent. causes a candle to cease burning." "It is decidedly prejudicial to breathe for any length of time, air containing one per cent. The air in the latter case becomes soporific, depressing, and altogether injurious." Writers on ventilation recommend that the amount present should never be greater than .2 of one per cent. Taking, as is given by some writers, 3.5 to 5 cubic ft. as the amount of air actually vitiated by breathing alone, per man per minute, breathing at the very moderate rate of 30 to 40 cubic in. per inspiration with 18 inspirations per minute, would give .33 to .5 of one per cent. of vitiation. As a man laboring hard would certainly breathe more air than this, the vitiation would probably reach one per cent., which was too large to be permitted.

I assumed therefore, a purity of .33 to .5 of one per cent. as being desirable, giving at once from $\frac{8.08}{.0033} = 2424$ cubic ft. to $\frac{8.08}{.005}$ =1616 cubic ft. per minute as the necessary supply.

Our compressors throw 3 cubic ft. of air per revolution, and make 60 to 80 revolutions; hence it was necessary to run at least 8 of them to keep the air wholesome. As we had previously run from 4 to 6 only, orders were given to ventilate the chambers by blowing off at frequent intervals, and no trouble was experienced afterward. The fact that more air was needed for health than was necessary to supply the waste by leaks, was one of the leading reasons for its use in removing the material excavated.

Subsequent to this investigation, when 10 to 12 compressors were in constant use, the air of the caisson was tested for carbonic acid, and about one-third of one per cent. found to be present, thus verifying the previous results.

HEALTH.*

There has been so much adverse criticism by the public press on pneumatic foundations, on account of the fatality attending

* RULES FOR THE WORKMEN IN THE CAISSON.

1. Never enter the Caisson with an empty stomach.
2. Use, as far as possible, a meat diet, and take warm coffee freely.
3. Always put on extra clothing on coming out, and avoid exposure to cold.
4. Exercise as little as may be during the first hour after coming out, and lie down if possible.
5. Use intoxicating liquors sparingly; better none at all. It is dangerous to enter the Caisson after drinking intoxicating liquors.
6. Take at least 8 hours' sleep every night.
7. See that the bowels are open every day.
8. Never enter the Caisson if at all sick.
9. Report at once to the office all cases of illness, even if they occur after returning home.

them, this paper would hardly be complete without giving the result of our experience in this regard.

On the Brooklyn side the men worked 8 hours, in two shifts of 4 hours each, down to the full depth of 44.5 ft., without injury. On the New York side the time was reduced to 7.5 hours, at 45 ft.; to 7 hours at 50 ft.; to 6 hours at 60 ft.; to 5.5 hours at 70 ft.; to 5 hours at 71 ft.; to 4.5 hours at 76 ft.; and to 4 hours at 77 ft.

The first fatal case, which was considered fairly attributable to the compressed air, took place at the depth of 75 ft., from congestion of the lungs. The man was recently employed, of very full habit, and had worked but one shift of 2.5 hours. He felt well after coming up, but died about an hour afterward. When examined two days before, his lungs were sound. What subsequent exposure he may have had, we do not know. One man died previous to this of cerebro-spinal meningitis, and one afterwards of Bright's disease of the kidneys; neither caused (although possibly hastened) by the work. One other new man died of congestion of the spine, due, no doubt, to the work. He also was fleshy, and, it is thought, of intemperate habits. Another fatal case was reported, the man having died, it is said, at home; the case is yet to be examined. There were perhaps a dozen cases of paralysis of considerable severity, but all recovered in from three days to three weeks. At from 50 ft. depth to the end, severe pains in the legs and arms (called by the workmen the "Grecian Bend") were frequent, but did not last long. Most of the cases were found due to disregard of some of the rules of health, which were furnished every workingman in printed form. The four rules certain to cause trouble, when violated, were the ones relating to rest, sleep, eating, and the state of the bowels.

At an early stage of the work on the New York side, a physician was employed to spend from one to four hours per day at the pier. His visits were always made in the afternoon, as cases of sickness on the early shifts were rare. At other times the engineer on duty, or some person under his direction, attended to the men.

The remedies employed were simple; prompt use of ergot and morphine would generally alleviate pains in the limbs; stimulants together with Jamaica ginger were given for epigastric pains. Where vomiting set in, and was persistent, the physician was sent for, as paralysis frequently followed.*

Coffee was always served to the men, immediately after coming out of the caisson. Bunks were provided also, in which all who wished, could rest. It would have been well perhaps, had the use of these been compulsory, as it was by no means general.

One important conclusion from the records kept of cases, is this: that the greater number of those who have retained their health throughout are wiry, somewhat spare men; while most of the sick, and all who died, were fleshy men, of full or large size.

Dr. A. H. Smith, the physician in charge, intends to publish his observations in full; and will be glad to receive any information regarding similar work, that he may get all available facts concerning the peculiar symptoms, sickness and treatment.

SAND PUMPS.

I have been requested to give a very brief statement of experiences in well-boring,† the only thing new in connection with which, as practised on the work, was the method of sand-pumping.

No difficulty was found in removing by means of the ordinary sand-pump, the sand and mud from the tube after driving, but the pebbles being of all sizes and exceedingly hard, whenever a layer of them was reached, the progress was vexatiously slow.

The drive pipe used was 6 in. in diameter. The sand-pump was 4.5 in. diameter and 5 ft. long, with a simple valve at the bottom; and when clean pebbles only were in the pipe, would frequently come up without anything in it. To overcome the difficulty I made an ordinary conical plunger of leather fitting loosely in the pump and attached to an iron plunger bar, heavy enough to carry the apparatus and lifting rope promptly down. The pump and plunger were lowered together, and then, letting the pump rest on the bottom, the plunger was worked with a sharp, short stroke, of course not far enough to lift it from the pump. At the very first trial of this clumsy apparatus, the pump came up more than

* It was found that cold water poured on the spine, or the part affected, and followed by friction, was of great benefit in all the cases.

† As a note to this paper, and not read before the Convention.

half full of pebbles; and the same success continued to follow its use.

This result could be reached more elegantly by having two tubes, each with a valve; a foot valve at the lower end of the lower one, and suction valve at the upper end of the upper one. These tubes could be arranged, the upper to slide over the lower, or over an intermediate one to which the lower was attached, and all to lift together when the upper is at the end of its upward stroke; a lifting rod heavy enough to sink the rope promptly should be attached to the upper tube. There can be no question that such a sand-pump would work well and save an immense amount of time if the valves were well arranged. It would give a positive lift, directly into the pump, in place of an accidental deposition as an effect consequent upon agitating the water by churning the pump up and down. This device was not tried, for the reason that it was not made until the borings were nearly completed.

Mr. J. Dutton Steele: There is one subject I would like to have a little light upon—it is this: the depth to which caissons can be sunk safely by using compressed air. During the consideration of the plan for the East River Bridge, it was estimated that the caisson should be put down as low as 105 ft.; and it was a subject of grave consideration with Mr. John A. Roebling and the gentlemen in consultation with him, whether that depth could be attained with safety to the workmen; and if of delicate physical organization, they would not be destroyed by the pressure induced. That caisson has gone down 80 ft., and the result is as feared—the pressure was hazardous to persons delicately organized. It is stated that a caisson at St. Louis has been put down 110 ft., which indicates that 30 ft. deeper can be as safely sunk there, as that which has been reached in New York.

Was this depth of 110 ft. occasioned by a temporary rising of the water, or was it a steady pressure? An accurate knowledge of the facts ascertained is important, since, as will be seen, upon it depends our knowledge of the depth to which we can safely go by compressed air.

Mr. Katte: As my work is entirely upon the superstructure of the St. Louis bridge, and my observations of the foundations were only made at rare intervals when I was stationed in St. Louis, I can only state, that as far as my recollection goes, the greatest air pressure the men were subjected to in sinking the eastern abutment—which is the deepest—was something over 50 lbs. I am aware there was far less difficulty experienced from the effect of the air upon the men in the lowest foundations than in some of the others. The experience gained in the mode of treating the men in the former foundations seems to have been entirely efficacious. I forget the exact figures as to depth, but I think it was about 110 ft., with a pressure of about 50 lbs.

Mr. Collingwood: In the New York caisson, East River Bridge, there has been a moderate amount of sickness, and one or two deaths. The St. Louis caisson was sunk 30 ft. deeper, with similar results, indicating that still greater depths may possibly be reached.

The law practically admitted in adjusting the hours of labor in the caissons, both at St. Louis and New York, seems to be as follows: taking it for granted that 12 hours is the extreme time a man can labor without detriment to health, in an ordinary atmosphere; then, with a pressure of two atmospheres, or 15 lbs. additional pressure, he can labor about one-half that time; with three atmospheres, about one-third of that time; and with four atmospheres, about one-fourth of that time. In other words, the time is inversely as the pressures.

The men will not be injured, provided a proper time is given them to rest. In saying this, it does not follow that men should work continuously the number of hours thus indicated; experience shows the contrary; and the time of work has invariably been divided into two portions, with a reasonable interval between.

It seems that there is a possibility of accommodating the men, in this way to the pressure; the only difficulty is, the return to the normal pressure. It is clearly the duty of every member of the profession who has anything to do with such work, to make public, as far as possible, the remedies used under the circumstances.

Mr. McAlpine: I think Mr. Collingwood has struck out an idea. The compressed air acts as a stimulant; pretty much like those commonly used, and is ultimately exhausting. I fancy that is precisely the explanation of its effects. With one atmosphere a man may work 12 hours; and with an increased pressure the number of hours must be diminished. I myself have been

stimulated under this pressure, almost as if I had taken laughing-gas. With workmen whom I employed during a period of eight months under a pressure of from one to five atmospheres, there was nothing that caused the slightest inconvenience, except when the pressure was put upon them too suddenly. By gradually increasing the pressure no unpleasant effects were present or visible.

MOUNTAIN RAILWAYS.

From "Engineering."

The time has long since passed when railways were considered luxuries adapted only for comparatively level tracts of country, or for districts through which it would pay to form a line with very moderate gradients by the execution of expensive tunnels, cuttings, or earthworks. Now engineers do not hesitate to lay out railways across mountainous districts in which previously even roads were almost unknown, and so long as a reasonable amount of traffic is likely to be forthcoming, capitalists are to be found who are willing to advance the means for making such lines substantial realities. In central and northern Europe, in Spain, in India, and in America, both north and south, mountain ranges have already been scaled by the iron road, and every day the locomotive is making its way through the regions of cloudland at elevations unthought of some thirty years ago. Thus, in Peru, the Cordilleras are crossed by a railway at an elevation of 12,200 ft., while the summit level on the Lima and Oroya line, now in progress, will be still higher, namely, 15,000 ft. above sea level.

Notwithstanding the experience already gained in mountain railways, however, it cannot be said that the best system of working such lines has been thoroughly determined upon. We are quite aware that the great variations in the character of the traffic and in the nature of the country to be traversed prevent any single system from being applicable in all cases; but what we wish to point out is, that even in cases where the circumstances are practically identical the best mode of laying out and working a mountain line is far from being universally agreed upon.

Broadly speaking, mountain railways may be divided into two great classes, the first comprising those lines which cross a mountain range dividing two level districts from each other; and the second consisting of those railways which connect a hill district or elevated plateau with the plains below. In the case of lines of the first class, the exchange of traffic is as a rule almost entirely between the two low-level countries, the hill districts furnishing but an insignificant portion of the whole. Under these circumstances it is evident that practically the whole of the tonnage transported has to be lifted to the summit level and lowered again, and if the traffic is important the expense of doing this becomes so great as to warrant the expenditure of large sums to reduce the summit level by resorting to tunnelling. Such, for instance, has been the case at the Mont Cenis, while in the case of the St. Gothard similar considerations have led to the adoption of a tunnel for that line also. We thus see that in the case of railways of the first-mentioned class the height of the summit level in any given instance—and consequently the amount of climbing to be done—is determined by the nature of the traffic, the heavier that traffic the lower being the level to which it will pay to reduce the summit by resorting to tunnelling.

In the case of railways of the second class, the circumstances are materially different. If the traffic has to be conducted between a low-lying country and a hill district situated, say, some 5,000 ft. above it, all goods passing from the lower to the higher level must necessarily be lifted this 5,000 ft., and all that can be done by resorting to tunnelling or heavy works is to obtain favorable gradients, and to avoid, as far as possible, any intermediate rises and falls between the upper and lower termini. As a rule, also, when high and low level districts are connected by a railway, the heavy traffic is down hill, and consists chiefly of mineral products. There may be, of course, exceptions to this rule, but it is one which very generally applies.

In may be noticed here that, although in working both classes of lines it is important to reduce the dead weight of the rolling stock to the lowest possible amount, yet

that this reduction has especial importance in the case of lines of the second class. Thus, for instance, in the case of lines on which the trains ascend loaded, a reduction of 25 per cent. in the dead weight of the vehicles may effect a reduction of some 10 or 12 per cent. only in the gross weight of the trains hauled by the engines, whereas in the case of a line of the second class, in which the trains ascend almost empty, a reduction of 25 per cent. in the dead weight may reduce the gross weight of train hauled some 20 per cent., or even more, and may thus effect a proportionate reduction in the engine power required.

Of the various modes proposed for working mountain railways we do not hesitate to say that none yet tried have on the whole given such satisfactory results as the employment of the locomotive. In saying this, however, we are quite ready to admit that exceptional circumstances sometimes occur under which it is advisable to abandon the ordinary locomotive in favor of other arrangements. Thus, in the case of the Mount Washington and Righi lines, where it was desirable to be able to surmount gradients as steep as 1 in 3 and 1 in 4, the adhesion of plain wheels on the rails would have been useless, and the plan of employing a rack geared into by a spur wheel on the locomotive was adopted with advantage; while in the case of the San Paulo line, where a lift of 2,250 ft. had to be overcome in a distance of about 5 miles, we consider that the engineer, Mr. Brunlees, exercised a wise discretion in resorting to rope haulage. We believe, in fact, that rope haulage might, with material advantage, be employed on mountain lines to a far greater extent than has hitherto been the case. The plan of hauling trains up inclines by means of ropes worked by stationary engines has hitherto been regarded with no very favorable eyes by railway engineers, and it is true that the results obtained in many instances where the system has been tried have not been such as to gain it an unexceptionable character. We consider, however, that to a great extent this result is not so much due to the inherent defect of the system as to the unfavorable circumstances under which it has been tested. A winding rope gives the best results when acting vertically, just as a locomotive works to greatest advantage on a level line, and according to the inclination of the line of haulage so will the balance of advantages be in favor of the rope or locomotive respectively. To get the full advantage of the rope the lift should be made as steep and as straight as possible, and should, as far as circumstances will allow, be concentrated at one point. Of course with very steep lifts special arrangements for carrying the ordinary rolling stock will be needed; but even with the steepest lifts there would be no mechanical difficulty in insuring perfect security for the trains during either their ascent or descent. If railway engineers would bear in mind the millions of tons of materials raised annually from our collieries, and, on the whole, the comparatively few accidents which occur to winding machinery, even under management which not unfrequently errs on the side of recklessness, they would, we think, have more faith in rope-worked lifts for mountain railways.

Setting aside the special circumstances to which we have adverted, however, there can be no doubt that the locomotive in some form or other offers practically the best means for working mountain lines at present devised. We believe that there are very few mountain ranges on which a line having gradients of a steepness not exceeding 1 in 20 cannot be laid down, and whenever such a line is to be worked, we should prefer trusting to the adhesion of a smooth wheel on a smooth rail rather than resort to any more complicated expedient. In countries where fuel is dear, or water scarce, it is, however, particularly desirable to obtain the flattest gradients possible in order to reduce the amount of locomotive power required to perform a given quantity of paying work. How important an influence the steepness of the gradient exercises on this matter, a very little consideration will show. Let us, for instance, for the sake of simplicity, disregard all frictional resistances, and suppose the work to be done to consist only in overcoming the action of gravity, and let it be further assumed that with efficient sanding apparatus, an adhesion of one-fifth can at all times be secured. Also let the gross weight of engine and train to be taken up be in all cases 100 tons. Then, on an incline of 1 in 50, the resistance to be overcome would be 2 tons, and the adhesion weight required 10 tons, or 10 per cent. of the gross load; on 1 in 40 the resistance would be $2\frac{1}{2}$ tons, and the adhesion weight necessary $12\frac{1}{2}$ tons; on 1 in 20 there would be 5 tons resistance, requiring an adhesion weight of 25 tons; while on 1 in 10 the resistance

would be 10 tons, requiring an adhesion weight of 50 tons, or half the gross load. It will be seen from this that so long as the adhesion weight available is simply that of the locomotive, the percentage of paying load which it is possible to take up, diminishes very rapidly as the steepness of the gradients is increased, and hence, in many cases, commercial considerations would impose a limit on the steepness of gradients permissible considerably within that rendered necessary by mechanical reasons.

But there is really no reason why the adhesion weight available should be limited to that of the locomotive. Long ago M. Eugene Flachât proposed the plan of fitting each vehicle of a mountain train with a cylinder supplied with steam from the engine boiler, the piston of this cylinder driving one pair of wheels direct, so as to render a portion of the weight of each carriage available for adhesion. M. Flachât's plan has never been brought into regular practical operation, but it has certain good features, and we believe that in a modified form it will yet be employed. To insure its success, however, it must be adopted in a form differing considerably from that proposed by its originator, and in particular two important conditions must be satisfied. The first of these conditions is that the train shall be hauled at a very low speed, while the second is that a high speed shall be secured for the pistons of what we may term the auxiliary cylinders.

The amount of adhesion which any given locomotive boiler power is capable of using up depends entirely upon the speed at which the engine travels. Thus, if by the evaporation of a given quantity of water per unit of time an adhesion weight of 30 tons can be utilized when travelling at a speed of 10 miles per hour, then if the speed be reduced to 2 miles per hour, it will be possible, by the same expenditure of steam, to use up an adhesion of 150 tons. In order, therefore, that the auxiliary cylinders applied to the carriages of a mountain train may be supplied with steam from a boiler of moderate dimension, it is absolutely essential that a very slow speed should be resorted to, and on the majority of mountain railways this slow speed would, we believe, be no serious disadvantage.

Again, the carrying wheels of the train making but few revolutions per minute, it is desirable, in order that the requisite power may be developed without employing large cylinders and heavy moving parts, that a comparatively high piston speed should be employed in the auxiliary cylinders. This means that, instead of driving the carrying wheels direct, as proposed by M. Flachât, the auxiliary cylinders should communicate motion to these wheels by gearing. By adopting this system the auxiliary cylinders could be made of very moderate dimensions. It may be noted here that the auxiliary engines on the carrying vehicles, would not require to be fitted with reversing gear, as they would only be used on the gradients, and be run in one direction. On the level portion of the line the train would be under the command of the locomotive.

IRON PIERS IN SCOTLAND.

From "The Mechanics' Magazine."

On the Clyde, an iron pier has been erected at Carradale, on the Campbeltown passage, which, in respect of its novel construction, merits description. The piling consists of old rails with a large cast-iron disc or shoe attached to their under part, sunk to the required depth solely by their own weight, the displacing of the sand being effected by means of a water-jet. The pierhead, which is 25 ft. wide, consists of three rows of piles, braced and cross-braced by horizontal struts and girders, to which the fenders are fixed; and the piles alternate so as to distribute any strain to which the structure may be exposed. The gangway leading to the pierhead has a floor of 6-in. planking, and is formed by 3½ iron arches with spans of 40 ft. The chief pierhead is constructed in two separate floors, one being 4 ft. lower than the other, and connected by a ramp at the back.

At Brodick also (Island of Arran), another iron pier, similar in design to the above, is being erected. This iron pier is in a forward state, and is expected to be finished for the summer traffic. The chief recommendation of these iron structures is their great durability, without greater cost than similar erections in wood.

An iron pier is also in course of construc-

tion on the Greater Cumbrae, four miles east of Bute, and two west of Largs. The pier, which was commenced in July last and is now on the eve of completion, is 275 ft. long and 18 ft. broad, widening out at the seaward end to a T-shaped head, 80 ft. by 25, for the convenience of vessels lying alongside. The structure rests on cast iron piles screwed in some cases and driven in others(according to the stratification) from 5 to 6 ft. into the ground. These are placed in pairs at a distance of 18 ft. apart, and are strongly braced together transversely. On the top of each pair of supports are placed cast-iron transverse girders, on which rest wrought-iron continuous lattice girders 4 ft. deep, that support the roadway, and also form the parapet to the pier. The roadway is of timber laid on rolled iron joists, which are riveted to the under side of the main lattice girders. The piles at the head are of wrought-iron, 7 in. diameter, in four segments, firmly riveted together at flanges; and in four cases these are carried up above the platform to form supports for cast-iron mooring bollards. The lattice parapet is not carried round the head, but the platform is here supported from underneath on rolled joists. Fender piles and wallings of American elm are placed in front of each seaward pile at the head.

In the construction of Toward Pier, in 1863, various experimental piles were driven, for the purpose of testing the sort of timber that could best withstand the action of the teredo navalis, the limnoria terebrans, and other marine insects. These comprised Bethel's patent creosoted timber piles; others clad with copper, zinc, and Muntz's patent sheathing; Quebec red pine covered with wrought-iron pile nails about 1 in. sq. on head, $\frac{1}{8}$ in. thick, and weighing about 3 lbs. per sq. ft. of timber; larch with the bark on; greenheart and elm fenders. The result was that the elm was eaten through in about four years, or at the rate of 1 in. per annum; the larch stood about seven years; the Quebec red pine, without protection, lasted for nearly the same period, while that creosoted remains still uninjured, together with the greenheart and the piles covered with the sheathing and nails. The Toward Pier, during its erection, was an object of some interest. The site being openly exposed to the cross seas of the firth, not a few doubted whether the structure could have stability, but it has proved to be durable. The length of its masonry approach is 85 ft.; of timber bridge 260 ft., by 16 ft. broad; length of pierhead 126 ft., and breadth 25 ft.

PILLARS vs. LONG WALLS AS SUPPORTS IN MINES.*

From the "Mining Journal."

In dealing with the various modes of working the stratified deposits, we have looked at pillar working and the various modifications of that system, leading us to a principle of working by which, in the immediate neighborhood of the men at work on the face of the coal, the roof is allowed to break in, and it is necessary for the men to protect themselves by packing and temporary walling, composed of broken material from the roof or partings. Notwithstanding pillar working produces open spaces in which fire-damp may accumulate, that mode of working, or modifications of it, is employed not only in our northern coal fields, but in various other districts of England, as well as on the Continent. When we remember the simplicity of its commencement—driving a board or stall to enable the men to work forward with safety, and then leaving a pillar between that and the next stall, the principle seems so convenient and natural that we do not wonder it should arise in various districts, independently of one another. The mode of long-wall working is distinctly contrary to pillar working in all the more important features. It aims from the commencement at the removal of the whole of the useful material, or such a large proportion of it, that no attempt is made to sustain the roof with any pillars at all. The men are protected close to the face of the working, and allow the roof to fall behind them, upon the refuse they have thrown there. This method is well seen in Staffordshire, where the flat measures are laid out in a wide and artificial manner, but where the workings are extended, so as to be called long wall—a method of the highest importance, and

* From a lecture before the Royal School of Mines.

one greatly used in this country, chiefly in Derbyshire, Leicestershire, Shropshire, and parts of Lancashire. There are modifications in practice in other parts of England, and in Scotland. By this method they are enabled in Somersetshire to work seams of coal of wonderful thinness—no more than 12 or 14 in. thick—with advantage. Again, long wall is worked in a number of foreign districts, modified occasionally by difficulties of roof and floor, and in Belgium, the North of France, Westphalia, and Saxony, by the high angle of inclination at which the seams are titled. In fact, the system is not limited to any district. It is a question, however, whether it is not a method capable of being applied in more instances, and where hitherto it has not been known; and the system is now occupying the attention of mining engineers, and making its way into districts where till lately it was but little understood. This system of getting the whole of the coal and leaving no pillars is best applied where the beds are favorably placed, and where the conditions are suitable. Take, for instance, beds of ironstone, in getting which a great portion is to be left behind as refuse, and which being placed properly in the gob, the roof is not let down to any great extent. In some instances, in beds of coal or ironstone of moderate thickness, the long wall method may be applied, even where there is little refuse with which to pack the empty spaces. In kirving coal there is always an amount of refuse to put in the gob, which assists to keep up the roof; but the presence of a great deal of rubbish is a great advantage when the seams are of more than average thickness. I am speaking of seams not exceeding 10 ft. in thickness; anything beyond that has to be wrought by special means. The principle of long wall working is very easily explained. Around the foot of the shaft (referring to the plan of a Scotch colliery) a large body of unwrought coal is left, and a couple of levels are driven out on the breadth of the coal (the levels in other workings being on the rise), and taking the coal between them in a stope-like form. And so in another diagram the workings are on the ascent or rise of the coal, and a drift is run out, which leads to a second pit, which is used for ventilation. The roof is kept up behind the men working on the face by means of props behind them.

It has been suggested that the putting in of props should be enforced by legislative enactment, and that no roof should be left unpropped for more than a certain distance; but having visited a great number of mines, I am strongly of opinion that any such enactment would be unwise, not to say futile and useless. The nature of roofs differs so materially in different districts, and sometimes in the same mines. Very often the men can work for a considerable distance with perfect security, while in other places a great many props have to be put in. Sometimes a roof will exhibit a number of circles, which are, in fact, the stems of fossil trees (Sigillaria) changed to hard shale or sandstone, or not unfrequently ironstone, and, being of conical form and smooth surface, are apt of to fall without a moment's notice, and crush all beneath; and whenever this formation is observed, a prop ought immediately to be put under it. Suppose, however, we have an average kind of roof, there would be no special difficulty, and the props may be placed 8 or 10 ft. asunder, and on two rows alternately, thus ⋱⋱⋱. The roof at the back of this will come down at shorter or longer intervals after the working of the coal, and the refuse and smalls will often be several feet in height, and fill up half the place. As a general rule, the roof breaks down not far behind the last row of props. The props themselves will for a long time be fit when taken from behind to set up again in front, but the lid-pieces are frequently smashed by the pressure. Working on the face in front of the protecting props, the miners complete the holing of the coal, and then the pressure will often cause it to come down of itself, or it is broken down by wedges, or gunpowder, or hydraulic force, and it would be well if the latter were more frequently employed. The coal having been brought down, it is removed, and then the men take down the back row of props, and set them in front on the face of the coal. The removal of the props is a matter of some danger, and has to be performed with judgment and quickness. They are generally pulled away by a chain or a rope fastened around each one near the foot, and sometimes, when the pressure aloft has been great, it is necessary to dig around the foot, and loosen it. There are, however, cases in which no amount of propping is enough to keep the men in real security; hence a plan has come into use in the North of England of building up pillars of chocks or nogs of timber, in pieces from 2 to 2½ ft.

long by 2 or 3 in. sq. These pillars are found to be exceedingly strong, and capable of sustaining a heavy roof pressure better than props, which are frequently driven by the weight into the soft floor. This, in a few words, is the principle of advancing the face of coal, whether that face runs in a long continuous line, or whether it is arranged in steps; and in Leicestershire the system is carried out with great success with working faces from 300 to 800 yards in length.

I will say a word or two more on the subject of the boundary. If is, as I have before said, important whether the work is carried from the centre outwards, or whether a pair of levels is driven out to the bound, and the mass worked by "bringing the coal back," as it is called. According to choice made of these two plans the arrangement of the roads will be governed. If, as the work proceeds, we go further from the centre, we shall have to keep up the communication by means of branches or parrallel roads; and the way of doing this is by packing the refuse material, and forming walls from 6 ft. to 12 ft. in thickness, and putting them in all shapes, so as to make the roof rest upon them. In this way the roads are kept open through the goaf or gob. The pressure of the superincumbent weight makes the floors of these roads puff up, sometimes to a great extent, and the creep has continually to be cut away. After a short time the roof, as well as the floor, will encroach on it, involving the continual employment of men to re-lay the rails and to cut away the roof, so as to keep it suitable for the passage of horses and other traffic. Sometimes it is found necessary to adopt the raised floor, and then a good deal of over-cutting will be required to obtain sufficient head room. In many cases within a very short time, the pack walling may be pressed into a third of the height it originally had, and it will be so squeezed down as to be a source of contant danger. The expense, therefore, of keeping open these roads is considerable, and must always be kept in view when the question arises as to the plan of working to be decided on. In Staffordshire they have a system of leaving a certain thickness of coal alongside the levels to keep them in good condition as travelling roads; and their lines of road will be carried to the face of the work only when necessary, and no more be put in than is sufficient to bring away the material; the necessity of seeing that the walls, or ribs of coal, do not at any point give way being imperative. Where there is only a moderately good roof, the coal is brought along the face in hand-wagons, pushed by boys, until the road is reached, when it is then passed along to the shaft. When the roof is especially good, and they are enabled to lay down rails and put on tram-wagons, the work is greatly facilitated, and they are enabled to convey the coal along the face so economically that it is not necessary to have the roads so close, and they may be even as much as 30 and 40 yards apart. In cases of this kind, long wall working is by for the most advantageous. At Hetton, where the works were laid out at first on the post and stall plan, the pillars are got by the long wall system; otherwise it would be a most expensive operation to move the coal from the face of the roads, which are by this plan only 12 or 14 yards apart. The arrangement of the workings then will be found to vary somewhat according to circumstances, the principle remaining the same; and much, therefore, will depend upon the experience and judgment of the manager, who ought to be conversant with all variations which have been proved to be best for economy and security at the same time.

What is called "broad working" is only another form, which can scarcely be called a modification of the long wall system, although an important one. The pits being sunk, levels are driven out to the boundary, and the coal being got adjacent to that line it is brought back to the shaft. In this plan there is a great advantage in leaving all the worked-out ground behind, and as the gas has a tendency to rise by its specific lightness it passes into the goaf, and is got rid of in the innumerable vacant spaces which are left in the broken material. In other systems the goafs containing these dangerous reservoirs of explosive gases must be continually traversed, while by this plan they are all left behind. Again, the only roads to be kept up are the narrow exploring drifts to the boundary, which being in the solid coal do not require any of the great expenditure required by the constantly changing character of the goaf in the maintenance of gob-roads. Wherever this plan can be carried out it will be found to have many advantages, particularly that of being very economical so far as the working and maintaining of the roads are concerned, and also that of greater security,

inasmuch as the worked ground is left behind in a condition in which it can do no harm. There is, however, one palpable objection to it—that after sinking shafts and putting up engines, particularly if the district to be worked be large, shareholders will generally be unwilling to wait until drifts are carried to the farther end of the ground. Sinking the shaft alone may occupy two, or three, or four years, and then driving out levels of such a length may take some years more. So that if the lease be for (say) 21 years no man in his senses would defer getting coal for so long a proportion of the time, as the period left would be too short for him to recoup himself. Men are obliged, therefore, in self-defence to begin getting coal for the market as soon as they can after starting from the bottom of the shaft. To that reason may be attributed the objectionable plan of opening large spaces near the shafts, and considerations of this sort militate against the theoretical completeness and advantages of working back from the boundary.

There are several modifications of these forms of working which are well worth notice; such, for instance, as when stonework arching may be employed to protect the roadways. This is notably the case in South Wales, where it answers admirably, the only drawback being the great expense of it. Many cases occur in that district where the best timbering cannot be maintained for any length of time, and, therefore, arching is found to be absolutely necessary. Some modifications have been tried in the North of England during the last 20 years, but they have been very successful in all districts. The long wall plan has latterly been adopted at the Monkwearmouth Colliery, upon the celebrated Hutton seam. The shaft there is 280 fathoms deep, and the temperature being 80 deg., the difficulties of working are considerable; but, nevertheless, this system has been applied with success. Parallel roads are driven 30 yards asunder, and these roadways are 2 yards wide, kept open and secured by pack walls. Thus, there is never more than 14 yards to carry the coal along the face to the wagons, the men being protected chiefly by chocks, the pressure being exceedingly great. Although the character of the roof is such that it breaks down immediately behind the back row of props, there is a much smaller proportion of small coal made by this system than by that of leaving large pillars. Besides which they are able to remove the whole mass of coal, and by its greater simplicity of plan the ventilation is more effective and more easily managed. Besides all these advantages of the long wall system, it is probable that it is far more secure, as regards the lives of the men, than other systems.

Then, again, modifications have been introduced to meet the circumstances which have made the South Yorkshire coal fields so dangerous. The workings at Lund Hill and other collieries in that neighborhood, which have been so productive of accidents, have been replaced by a system analogous to long wall working, which has been found of great advantage. In the Forest of Dean, on a seam of coal 11 ft. thick, which some years ago would hardly have been thought a suitable subject for working by long wall, two distinct systems are now in use, in both of which the necessity of driving narrow levels is got rid of. The roof at the face of the working is supported by props, and a slice being holed and taken down, the space kept for the roadway is packed on each side. The props being then taken away, the roof comes down, leaving the roadway to a pressure resulting in a heave of the floor, which has to be cut away, while the roof also has to receive similar treatment, so that half the roadway will be in the roof, the original coal being compressed sometimes from 5 or 6 ft. to 1 ft. If we have a bed of chert in the middle of a seam of coal it is advisable to begin the holing in it. Thus, suppose we have a seam of coal 50 ft., above that a layer of chert 3½ ft., and above that 3 ft. of coal, we must take out that beneath the chert first, and support the chert and top coal by chocks of wood, and then as the bottom coal is removed, taking down that above close up to the chocks. By this plan in the Forest of Dean they get a smaller proportion of slack than they would by any other means. In Scotland the long wall system is largely adopted. It is generally deemed preferable there to trust to a packwall than to coal for the roads, although the floor often heaves. The face of work often advances very irregularly, a good deal, probably, because of the irregular direction of the cleat, or, perhaps, because the coal works better on the end than on the face. The long wall system can be made so economical that in Somersetshire seams of coal as little as 30 in. are worked—indeed, I have

seen a seam of 11 in. only, worked by this method. For the same reason many of the pillar workings in Yorkshire have been transmogrified into the long wall system by advancing the bord gates, and enlarging the faces of work. The great length of gob roads to be kept in repair has been the main objection to the change, but that has been got over by driving a few yards uphill, and working a portion to go to goaf, thus making the two systems work into each other.

The long wall system is carried out in Lancashire, Nottinghamshire, South Derbyshire, Shropshire, in certain parts of Staffordshire, and in the Forest of Dean. Its introduction into the North of England has only made any way within the last few years, but it is now adopted in some of the Northumbrian and Durham mines. It is largely used in Westphalia, Saxony and Belgium, varying much, no doubt, according to the different thickness of seams, their inclinations, and local circumstances. Indeed, the forms into which the workings may be thrown, and the modifications of which the system is capable, are innumerable, and it is therefore impossible to lay down exact rules. The roadways up to the face of the coal, however, should not be more than 30 yards apart, as it is not desirable to have to drag more than 12 or 15 yards. The working by long wall should go on with a regular out-put; that is to say, that side by side with the quantity required for the market the work should advance regularly every day. Strikes of workmen, or a want of a sufficient sale, or water getting in, or anything which will interfere with this regularity, will be fatal to the satisfactory employment of the long wall system. It may be said, however, in conclusion, that where the long wall system has been introduced it has soon been admitted to have a decided advantage over pillar working, in the economy with which the coal can be worked, and in the cheapness with which it can be broken down, and in the proportion of large coal which is obtained, besides being much softer and better for the workmen.

ISOCHRONOUS GOVERNOR.

From "Engineering."

M. Yvon Villarceau, Member of the Paris Academy of Sciences, presented recently to the Academy the results of his long investigation on governors, and exhibited an apparatus constructed upon his calculations by M. L. Bréguet, which realizes with wonderful exactness the results of the calculations. The isochronous governor is one which maintains a constant speed in a machine, in spite of the considerable variations that may occur in the work put upon it. The governor can maintain this constant speed either in acting upon the motor or upon the resistance. Thus, in the case of an engine driving machine tools, if a certain number of these are stopped, the governor acts upon the valve and diminishes the mechanical work done by the engine, bringing it down to the proper proportion with the tools still running. If, on the contrary, it is used to turn by the aid of a weight the bearings of a heavy astronomical instrument, and to obtain a uniform speed, in spite of possible variations, the governor is so arranged that the flyers connected to the moving parts, oppose to the air a greater or smaller surface, giving thus a varying resistance, which has the tendency to reduce the differences between the real speed as compared with the speed required.

M. Yvon Villarceau has worked out two theories, applicable to governors of two kinds, that is to say, to oscillating masses of various forms, spheres, cylinders, and parallelopipedons, and to flyers of different kinds. In the governor of the second kind, it is sought to obtain the most uniform movement possible; the exactitude with which the apparatus can be made to work, under the condition where the moving power varies in the proportion of 1 to 6, or beyond, depends entirely on the care which the maker has bestowed in working to the theoretical data, and the amount by which he has reduced the friction of the moving parts.

In spite of the greatest precautions, it will happen that the density of the metal employed will not be exactly that upon which the calculations are based, and the dimensions given by the maker will not be entirely in accordance with the drawings. From these causes arises a fault in the

isochronism, to correct which it is necessary to employ means for regulating the apparatus. This problem resolving itself into four equations, M. Yvon Villarceau has been led to combine four distinct variations, changing the mass of the body of the regulator, and the movement of three regulating bodies forming part of the main weight. Each of these plays a very important part in fulfilling the theoretical requirements. The flyers are trapezoidal in form, they are made of aluminium, in order better to approach condition of isochronism, the rods are of steel, and the other parts of the principal mass are of aluminium bronze. The apparatus is regulated in the following manner: The governor being connected with clockwork, the speed, ω, is observed that is acquired under the action of the moving weight, and the angle, α, the rods make with the vertical. The driving weight is varied, and four groups of valves for ω and α are observed. Thus experimental data are obtained necessary for calculating the necessary movement to be given to the regulating weights, and the required variations of the main body.

The regulation being completed in accordance with the theoretical requirements, if new observations of the speed are commenced, it will be found that, whatever will be the driving weight between the extreme given limits, there will be very little difference in the speed which it is desired to obtain.

Thus in the first trial made on the 20th May, 1870, the driving weight was subjected to variations between 1 and 6, and the speeds obtained showed an average difference relative to the mean speed, which only amounted to $\frac{1}{3\,5\,5}$ of the latter. Some faults in construction were corrected, and on a second trial the differences were reduced to $\frac{1}{1\,0\,0\,0}$. Putting the driving weight to its maximum of 264 lbs., variations in the resistance were produced arbitrarily by means of a brake. In this way 51 observations were made in 30 min., which showed that the average variation of the governor, as compared with the chronometer, was only 0.2 sec.

M. Yvon Villarceau remarked, in conclusion, that M. Bréguet, in his first trial with the new apparatus, attained a great degree of precision. He was happy to produce before the Academy a new proof of the injustice of the accusation often made against mathematical theories, confounding these theories with false applications which have been too often made. In this case the application has been made with such care that the maker has not made the least departure from the dimensions and the weight given on the drawings. At the request of M. Bréguet, M. Villarceau made in his name the declaration that this was the first time during his long career that he had ever known a pure theory carried perfectly into practice on the first trial.

OUR MAIN DRAINAGE.

From "The Engineer."

In spite of some serious shortcomings which have been recently apparent in the metropolitan main drainage, we may be justly proud of the system as it is carried out, as a whole. It is quite possible that it may leave undone some duty that it ought to fulfil, but balanced against the omission must be considered the many and various duties which it does discharge in a very satisfactory manner. Without regarding the question of the ultimate disposal of the sewage of a city containing the population of London, the mere conveying it away rapidly and innocuously from the habitations of the people is no mean task. Whatever plan may be adopted for the subsequent utilization of sewage and refuse matter, the first step is to effect in a prompt and economical manner its removal from the vicinity of its original deposition. Unless this removal be accomplished at once, and moreover thoroughly be effected, it is impossible to insure the sanitary welfare of those who may thereby be concerned. It cannot be too carefully borne in mind that the idea of obtaining profit out of refuse must never be permitted to be practically realized at the expense of the health of the community at large. It is for this reason that the water carriage system of drainage and sewerage will never be superseded in the case of large towns by any of the earth-closet methods, which, it must be admitted, have done good service in particular districts and localities for which they are well adapted. The universal application of the

dry-earth principle is a hobby which it is but natural some people should cling to, who are incapable of distinguishing between a rule and its exceptions. At the same time, any scheme which professes to deal with the drainage and sewerage of a town cannot be said to be a complete one, or thoroughly to effect that which it ought to accomplish, so long as its operations are confined solely to what may be called the cleansing of the streets and closets. There is a wide difference between the transport of sewage and its profitable utilization, and the latter has not followed so fast in the rear of the former as might be expected. In fact, unless land can be obtained at something approaching a reasonable sum per acre, the profitable utilization of the sewage of a large town is an impossibility. Nothing less than a fabulous return could possibly repay the ratepayers in many instances the extortionate prices demanded of them for land required for the purposes of sewage utilization. Viewed in the light of a complete drainage and sewage scheme, our main drainage obviously falls short of what it ought to be. It entirely ignores the question of the utilization of the sewage and refuse matter which it conveys away so rapidly and efficiently from the metropolis. The transport being accomplished, there its operations cease, unless, indeed, we take notice of the subsequent discharge of the material into the Thames, which occurs north and south of the river at the pumping stations.

In connection with the efficiency of our metropolitan main drainage there are two points to be considered. In the first place, is it really adequate to perform the duty properly belonging to it? In the second, is it complete? We do not use this term in the same sense as previously, but regard it as applying simply to the question of drainage. It is well known that our London sewers and drains are intended to carry off, not merely their ordinary contents, but whatever storm water may accumulate in them. Many intercepting sewers were laid at various depths along both banks of the river for this purpose, known as the high and middle level sewers, and have now been in operation for some years. Some idea of the length of these arterial drains may be gathered from the fact that the main sewer which intercepts the sewage from Chelsea Bridge to Abbey Mills pumping station is over eight miles long. It would appear, however, that there are still some parts of the metropolis which are under water during heavy floods. This condition of things can only arise from either the absence of all connection between the flooded districts and the intercepting sewers, or the inadequacy of the latter to provide for the emergency. If the former, it is not difficult to establish the desired communication—if the latter, the affair becomes more serious. It is a mere nothing when a sewer, situated at some depth below the surface of the ground, is being "got in," to alter its dimensions either one way or the other; but when it is once built and covered up, and a greater capacity is found to be required, the question becomes reduced simply to one of the building of a new drain altogether. This measure has been actually adopted in one part of London, and the cost of the new sewer from first to last will not fall short of £100,000. It might be asked, was the main drainage system intended to meet this case?—but in either case it is at fault. If it were not originally intended to take this drainage area, the design was theoretically imperfect. If it were designed to do so, there must have been some practical imperfections in it which prevented it doing so. This is a very different case from that in which all that is necessary is to make the connection between the main and the branch drains. At the present time there are numerous connections of sewers with the completed length of the low level line to be established, which must be a work of time, for two reasons. One is, that opportunities must be seized as they present themselves, as they cannot be obtained otherwise than at an unwarrantable expense. The other, that when occasions do present themselves, as the sewers have to be carried through some of the most crowded streets and thoroughfares of the city, the progress must be slow, and the whole labor tedious, troublesome and costly. Nevertheless arrangements ought to be made which would facilitate the laying of sewers and drains, and the construction of subways is an important step in that direction, provided power be obtained by the authorities to compel parties to use them. They should not be allowed the option of breaking up the streets instead, of which a notable instance occurred some years ago in Southwark street.

The question of the utilization of the sewage of London has not been entirely ig-

nored, though one would be almost justified in imagining so, from the fact that no tangible results have followed any consideration that may have been given to the matter.

Any company which undertakes the utilization of sewage stands on very different ground from local authorities engaged in a similar undertaking. In the latter case the ratepayers are satisfied if they effect thereby only a saving in their rates, but in the former the utilization must not merely be a profitable, but a paying concern. The English of this is, that after paying all expenses of manufacture, transport, and other items incidental to its sale, an artificial manure when manufactured by a company must command a price sufficiently high to return a good dividend on the capital invested. The question is, does it?

THE WATER METER AND ITS USES.

By C. H. C.

Written for Van Nostrand's Magazine.

The subject of maintaining our water supply has for a long time been a matter of very general and serious interest to the city of New York, and has aroused considerable discussion as to the most judicious method to secure such a satisfactory result. Its importance for all general requirements, as well as for any extraordinary contingencies which may occur, such as an epidemic or a wide-spread conflagration, cannot be overestimated. To attain this purpose the adoption of water meters has been prominently urged by those who have given the matter the most thorough investigation. A popular prejudice, however, against their use, founded upon very erroneous grounds, has been incited by misrepresentations, coupled with an imaginary expectation of an advance upon the present tax for the use of the water. Experience and facts are so diametrically the opposite to such a supposition, that we have made a concise statement of indisputable data, by which it can be seen that the use of meters affords the only method whereby the community can be honestly and fairly served. That, instead of enhancing the individual cost, it will reduce it, unless grossly wasted, and, by equalizing it according to the amount used, materially increase the revenue, and entirely prevent the direful wastage which now exists.

Meters for measuring water will be found an indispensable necessity wherever aqueduct water is used. The experience of the city of Boston may be aptly cited as furnishing a criterion for the guidance of other places, the subject there being no longer one of experiment or doubt. That city has in use a larger number of meters than any other in the Union. Aqueduct water was first introduced there in 1849; six years after, in 1855, the consumption averaged 10,346,300 gallons per day, and so rapidly increased that six years later (1861), it had reached a daily drain on the pipes of 18,189,304 gallons, an average of 102 gallons for each inhabitant, per day. The Commissioners becoming alarmed, and convinced that the greatest portion of the water drawn was wasted, decided to attach meters in all places where much water was used, or where they suspected waste of it was permitted. Previous to which, that they might correctly ascertain the quantity of water necessary for the daily consumption of each person, they caused meters to be placed in their own dwellings, and found that 25 gallons a day was more than an ample supply for each person. The result fully justified their decision. As the meters were introduced the drain *gradually* and steadily decreased till in 1866 it had fallen to 12,229,000 gallons per day, or to 58 gallons per inhabitant then, a falling off of 33 per cent. in the consumption, and gained 48 per cent. in the pressure. Had it increased *only* in proportion to the increase in the population (and the increase in the consumption of water is always considerably more) it would have been 21,577,062 gallons per day, or 76 per cent. more. In 1870, with a large increase of consumers, it had only reached a daily draft of 15,007,700 gallons, or less than 60 gallons per head.

As to the question of revenue. In 1861, with a daily consumption of 18,189,304 gallons of water, the revenue was $365,323.96. In 1866, the consumption having fallen to 12,229,000 gallons, the revenue should (in like ratio) have fallen to $245,613.94; but, on the contrary, by the use of water me-

ters it increased to $486,538.25; and in 1870, had reached $708,783.68.

The following comparison may justly be drawn: Repeating the figures, Boston, *without* meters, in 1861, consumed daily 18,189,304 gallons or $102\frac{2\,8}{1\,0\,0}$ per head; income $365,323.96. *With* meters, in 1870, consumed daily 15,007,700 gallons, or $59\frac{8\,6}{1\,0\,0}$ per head; income $708,783.68. Decrease in the consumption 3,181,604 gallons per day, equal to 17½ per cent. Increase in the receipts, $343,459.72 per annum, equal to 94 per cent., besides 21 per cent. gain in the head, and all this in the face of 41 per cent.* increase of population. *This extraordinary result was attained by the introduction of only* 1,108 *water meters at the comparatively insignificant expense of* $114,366.48.

The Water Commissioners of that city in their report of 1870, say: "*The application of meters has been of great advantage to the city, both as regards the increase of income and checking waste, which is always liable in establishments where there are a large number of water fixtures.*"

The foregoing facts can be verified by reference to their reports of 1870 and 1871.

The Croton Aqueduct Board, of which the Hon. Myndert Van Schaick was President, were so impressed with the necessity of measuring the water, that in one of their reports to the Common Council, nearly twenty years ago, they stated that they would recommend the general adoption of meters as soon as an efficient one was invented, although it might perhaps cost the city a million of dollars, for their introduction.

In a later report they say:

"No satisfactory estimate of the consumption of water at some of the manufactories and hotels can be made without the introduction of water meters."

"Meters have been placed on 68† large buildings, and have operated beneficially in determining the quantity of water consumed; the Board propose to extend the system in special cases of hotels, factories, etc., as circumstances may require."

And again in another report:

"As stated in the last annual report, water meters have increased in favor, and the consumer who could not be convinced of the quantity of water used in his establishment, has now a certain and impartial umpire, and though the result in almost every case is against the consumer, yet the decision of this small, but very costly apparatus is generally acquiesced in."

In reference to preventing waste, Mr. Craven, then Chief Engineer of the Croton Works, in a paper addressed to the "New York Evening Post," March 17, 1868, declared that he had exhausted every means and argument in his power to prevent, or even mitigate, this inordinate waste, but without avail; and that he had finally been forced to the conclusion, that the only possible way in which it could be accomplished, was by attaching meters wherever aqueduct water was used, and that the benefit to the city would then be immediate and of vast importance.

Mr. Tracy, now Chief Engineer of the Department, reports the daily consumption of water to be 88,000,000 gallons, which shows that with an increase of population in the last ten years, of only 17 per cent., the drain on the water works has increased 193 per cent.!!! besides considerable loss of head. It was 30,000,000 gallons in 1860.

Although at the greatest outlay of money ever used for a like purpose, New York has now the largest supply of Aqueduct water of any city in the world. The consumption being now, as stated, daily 88,000,000 gallons, or $98\frac{2\,4}{1\,0\,0}$ per head. Income in 1870, $1,178,341.34. Should the Croton Department receive remuneration for water in the same proportion as does the Boston Water Works, the annual revenue would be $4,156,104.12, but, for a lack of meters, New York loses annually now about $3,000,000, and yet the water rates of New York are professedly about the same as in Boston. *Vide* M. Hoffman's Laws of City and County of New York, vol. i., folios 274 to 288.

Compare now the distinctive policies of the two cities and their results:

Boston in the last decade, while it has increased in population 41 per cent., has *decreased* the consumption of water 17½ per cent., and in consequence *gained* in the head or pressure 21 per cent. So *much better* than ten years ago.

New York in the same period, with an increased population of only 17 per cent., has increased the consumption of water 193 per cent.!!! and *lost* in the head or pressure considerably. So *much worse* than ten years ago.

The reason is: *Boston decided to control*

* Partly by extension of limits.

† In operation now about 200 meters, being fewer than four years ago on a consumption of 62,000,000 gallons.

the waste and by the aid of Meters succeeded at a small cost. New York undertook to supply the waste without them, and after expending several millions has signally failed.

Profesor Rankine of Glasgow University, in an exhaustive work on the subject, estimates a *liberal supply* of water for cities thus: domestic purposes 15 gallons, commerce and manufactories 7, washing streets, extinguishing fires, supplying fountains, etc., 3; waste under careful regulations 2½. Total, 27½ gallons per head a day.

In London the water is all measured (by meters and otherwise). By the census of 1871, the number of inhabitants was 3,383,002, and the water supply in that year 77,670,834 gallons per day, equal to $22\frac{95}{100}$ gallons per head daily, and yet there is no complaint made of a scarcity of water for any healthful or necessary purpose—domestic, industrial, or public.

The London figures prove that New York with proper restraint of abuses has sufficient supply of water for about four millions of people, and yet with less than one million of inhabitants, by permitting an illegitimate, unnecessary and unpaid for use of the greater quantity of it, by a small portion of the people, is drawing so close upon the resources that there is a constant fear of a disastrous water famine; and justly so, for notwithstanding the enormous supply the numerous poor have to go unwashed, the pestilential sewers and streets remain unflooded, the public fountains continue dry, and for a large conflagration the city is totally unprepared.

Every person who has considered this subject, and many expert engineers and others possessing large property subject to the risk of fires, have given it most profound study; all have come to the same conclusion, that the adoption of meters is the only possible remedy. In fact, when once adopted the wonder will be why they were not used much earlier, the only ones to complain being even now habitual wasters or those not conversant with the subject.

It would be found at once that, while the majority of water takers do not use in their dwellings sufficient water to bring their tax up to the present rate, say about $15 per annum, thousands of others *designedly* letting it run constantly day and night in their water closets, use more than $1,000!!! worth of water, but pay only about $15 like the rest, and no one except their immediate neighbors are the wiser for it, for no means are used to ascertain the fact. When once they found the cost they would soon moderate their extravagant *hygienic* notions. It is the opinion of many that the bulk of waste is in private dwellings, and not in the public and industrial establishments.

The wantonness of this waste can be fully appreciated when it is shown that to bring this amount of water to their premises, it costs the city about $500 per annum (1 cent per 100 gallons; the interest alone on the cost of the works, $22,500,000, being about ½ of this cent), this excess of cost ($485) having to be paid in the general tax by those using only the $15, and even by those deprived of it altogether, in consequence of this waste.

The other great source of wastage is by subterraneous leakage through breaks in the conduit and pipes, and which secretly and imperceptibly finds its way into the sewers through underground fissures and crevices. These also are detected and its location and importance promptly ascertained by the general use of meters.

A very great injustice is also done the poorest classes who live principally on the upper floors of stores and tenement houses, for by the loss of head or pressure in consequence of this waste, the water does not rise to their habitations, and they are, as a general thing, too tired of work to be carrying up water in buckets, in sufficient quantities for purposes of ablution and general cleanliness, and yet they really need it much more than the rich.

Out of the increased receipts (chiefly from delinquents), *the meters pay for themselves invariably the first year, generally in six months, and often in three months.* The second year they are sure to bring the consumption of water to one half, or even less, in proportion to the meters used, raising the head correspondingly, and all this without disturbing the great majority of consumers either in the quantity of water used or the amount they usually pay. In fact a good many would pay actually less, besides having water in the upper stories.

In the annual report of the Board of Public Works of Chicago, of 1870 (which, after Boston and San Francisco, is using more Water Meters), they say: "*The Board have found the use of meters in establishments using large quantities of*

water, both satisfactory to consumers and profitable to the city." And in their report of 1871, they say: "*The prejudice which formerly existed against the use of meters is gradually giving place to a feeling of confidence in this method of determining the water assessment, and were it not for the heavy expense, the Board would like to introduce them more generally than they have done heretofore.*

Even continuing the present system of charges (according to the size of premises), meters would be invaluable; they would constitute a silent but positive corps of detectives showing any wanton waste, thus enabling the authorities to enforce the fines imposed by law, which at present is impossible as asserted by Mr. Craven. They would at once control the waste and raise the head, while the fines alone would in time pay the whole cost of their introduction. All the principal cities in the United States and some in Europe employ meters to some extent, England and Scotland largely; and the Governments of France and Belgium, in 1866, offered premiums for a reliable and cheap water meter.

So satisfied was the Croton Aqueduct Department of the absolute necessity for the introduction of water meters, as the only sure preventive of the excessive wastage of the water, that in 1867 and again in 1870, they called by advertisement on engineers and inventors for a meter that they might recommend for general use, and a large number of them were tried on both occasions. The result of the first trial did not terminate in any final decision, but to the later trial a wider range was given. More extended public notice was then made, and in the meantime a powerful and thorough apparatus was constructed to test them. The trial extended over three months, day and night, and of the large number offered, 48 of all kinds (*positive, proportionate, and inferential*) were tested, and of them 4 of the *positive* class (3 American and 1 Scotch) were selected as the best, finally resulting in subjecting these to a severer trial, which enabled the department to make a final selection of one of them. These trials and continuous experiments evince the decision made by these officials, that there was both a necessity for a more economical use of the water as well as that the introduction of the meters was the only feasible means of obtaining it.

It is the avowed opinion of the majority of Water Commissioners throughout the country that meters are a necessity, and that their *general* adoption is only a question of time; in fact they are being now rapidly introduced. A good water meter, however, is a very difficult instrument to produce, as is proved by the fact that during the last fifteen years over 500 patents have been taken out in this country, and over 300 in England, and none as yet had been able to supersede the one invented by Mr. Worthington eighteen years ago, and the only one used until lately in the United States.

The majority of these meters, no doubt, work and even make a good show at a trial, and a considerable number give great satisfaction to their friends, but when put to a severer and protracted test they usually fail or show signs of eventual failure from different causes, and *not one in a hundred* has proved a perfect *practical* success. A good reliable meter is a machine requiring such a rare combination of peculiarities that it is very difficult to attain. What makes a water meter more difficult and much more costly than a gas meter is the heavy irrepressible nature of water and its foreign matter, the high pressure, velocity and ramming under which it has to work, and the extreme delicacy and sensitiveness required of such a heavy machine. Also the necessity of *a perfect positive motion* with nothing like a dead centre, a weak place or a disposition to stop and refuse to start, and finally its capacity to do the work totally uncared for and neglected. If on these points it be not *absolutely infallible*, it is useless to talk of other advantages. In conclusion all these important qualities must be attained at a moderate cost, and this again has aggravated the difficulty.

No better evidence of these difficulties than the fact that after so many years of incessant study and labor and the large amounts of money expended in experiments, etc., by able engineers, inventors and others, in the production of over 800 patents only *three or four* meters have ever been accepted and practically used, either here or in Europe.

To be more explicit, *a first class water meter* should possess, among others, the following *essential* points of excellence:

1*st*.—It should be of *positive motion*, simple in construction, strong in form, and free of all springs, both metallic or rubber, or any bob weight to act as their equivalent.

2*d*.—Should *accurately measure* equally

well under light or heavy pressure, either a small or large stream.

3*d*.—Should require the *least possible amount of power to drive it*, thus avoiding reducing or losing the head or force of the water.

4*th*.—Should not be liable to injury or obstruction from *sediment or dirt*.

5*th*.—Should throw a *continuous*, smooth, and even stream.

6*th*.—Should shed the *greatest possible quantity* of water in a given time, in proportion to its size and weight.

7*th*.—Should *not cramp the water* within itself, but allow it a free, easy flow, thus avoiding as much as possible any strain or throbbing in the meter or pipes.

8*th*.—Should be of *incorrosive* material, avoiding if possible two distinct metals in order to escape galvanic action.

9*th*.—Should have a *register of positive motion*, without ratchets or springs, so plain that consumers could read for themselves, and full enough to run a whole year at full speed, without going round, thus saving people from more than an annual visit from the inspectors.

In conclusion, this matter is one which appeals to the interest of every citizen. It is unnecessary to detail the privations arising from a water famine, or the dangers which even a reduced and low standard of pressure may cause, because these are self-evident. The remedy is the point at issue, and we think when the subject is fully and fairly investigated it will be apparent to all that the use of meters guarantees the only entire security for a proper and efficient supply from our Croton resources.

SAFETY FROM LIGHTNING.

From "The Engineer."

The considerable number of accidents to houses, steeples, and other edifices from lightning stroke proves that, remote though the contingency of this form of damage may seem, yet the probability of it is sufficiently great to suggest means of prevention. The case presents no more difficulties than does that of the protection of water pipes against freezing and frost rupture; yet what architect or builder of a private house gives thought to either? As for the pipe-bursting part of the business, omission to guard against it can be explained. The consequences of this accident are more provoking than dangerous. Plumbers, plasterers, bricklayers, and occasionally other individuals of the building craft, find in this class of accident a small winter harvest. Called upon to repair the damage, they establish little accounts, which are presumably paid. It is good for trade, as goes the phrase; hence, the whole building craft rebel against pipe-bursting preventions as shoemakers would rebel against indestructible shoes, and cemetery managements have rebelled against indestructible coffins. As to lightning, however, it is a different matter quite. This is an agent not to be trifled with. When it strikes it does so seriously, putting forth a power more fierce and uncontrollable than all nature can match. Does it, then, not appear extraordinary that some means of averting the destructiive force of lightning, if known and possible, should not be commonly adopted? That such means do exist—means not only practicable but simple, and, more to the point, inexpensive—nobody can doubt who bears in mind what the late Sir William Snow Harris achieved in guarding ships of war against destructive lightning stroke by means of his system of conductors. Who ever hears of a British ship of war injured from lightning stroke now; yet how frequently did this happen before the Plymouth electrician took the case in hand, applying to practice his theoretical deductions? Like most great discoveries, the Harris lightning conductor is extremely simple. Before his investigations were carried into practice, a sort of opinion prevailed that the metal of a lightning conductor ought to be iron; but to Harris more than to any one else the merit is due of showing the superiority of copper for this purpose, inasmuch as it is a much better conductor of electricity than is iron. Before Harris, naval constructors had come to question the value of ship lightning conductors in any case. With good reason they might doubt, having regard to what these instruments were. They consisted, not of permanent fittings, as now, ever ready against a thunder-storm, and always

efficient, but of chains carried to the mast-head at times when a thunder-storm might seem imminent. Under the prevalence of this system an alarming number of accidents occurred, as might have been anticipated. For these iron chains Harris substituted continuous lengths of copper inserted into the ship's masts, the arrangements being such that, whether the upper masts were elevated or depressed, there should be permanent metallic contact. To Harris is due the application of the very obvious logical canon, that, if an electrical conductor be always trustworthy, and in no case dangerous, it should be implicitly trusted. The lurking idea that metal, by attracting electricity, might do more harm than good, sadly interfered with the practice of lightning conductors, more especially marine lightning conductors. Harris dissipated this fear, propounding and proving that metal no more attracts electricity than watercourses can be said to attract water; and to carry the parallelism a step further, it was shown that, similarly as a too small water channel provokes a damaging overflow of water, so the electrical capacity of a lightning conductor, to be universallly efficient, must be commensurate with the strongest lightning discharge ever yet experienced, and hence, from analogy, that may be expected. Electricity was up to a late period of its history looked upon too much in the light of an occult, inscrutable force for the interest of lightning conductors; but since the point has been established, that a copper rod of less than half an inch sectional area is electrically capacious enough, and to spare, for carrying harmlessly away the strongest lightning discharge ever known, architects and builders cannot plead ignorance of necessary data.

Now, to establish a copper rod of competent sectional area from roof to basement of a house is a more simple affair than that of establishing metallic connection throughout the entire length of a ship's masts, for a reason that will be obvious. Masts slide up and down, whereas the height of land edifices is permanent. The expense, moreover, is so trifling that objection on the scorce of economy would be futile. If every edifice in a town were thus provided, it is not too much to affirm that the most violent thunder-storm conceivable would be robbed of its destructive power for that particular area. The protective result of this general application of lightning rods would conduce to more benefit than may at a first glance be apparent. Not only would each separate building be insured against the ill effects of lightning stroke by the operation of its own particular rod, but each conductor would afford comparative immunity to human and animal life exposed to the storm and uncovered in the neighborhood. Neither would the most general adoption of lightning rods, if properly erected, mar the beauty of any style of architectural structure of whatever size or pretensions. In by-gone times, when disfigurements from this cause have resulted, they are referable to misconception of electrical principles on which the efficiency of lightning conductors depends. There was no sound electrical reason, for example, why a long spike should have been pushed through the bronze head of his Royal Highness the Duke of York—the statue, we mean, which surmounts the Duke of York column. A disfigurement so hideous and so unnecessary belongs to the teaching of a past electrical epoch. The statue itself being metal, safety would have been in equal measure insured through the establishment of connection between it and the earth by the intervention of a copper bar of sufficient sectional area. A lightning conductor need not, for efficiency, be carried down the frontage of a building any more than over the sides of a ship. It may be led down inside a house, if more convenient, and in a ship, even through the powder magazine, for any harm its presence there could accomplish—the truth being that electricity is only dangerous when interrupted.

If, seeing the ease and inexpensiveness of guarding against lightning damage, one wonders that conducting rods are not applied to private buildings more generally, the marvel is still greater that public edifices—especially churches with their steeples—are often equally neglected. Only the other day, a metropolitan church steeple gave us a practical example of this. The owners of factory chimney stacks are, in making this provision, usually more thoughtful than public societies.

Desirous as we are of seeing the adoption of lightning conductors made more general, a mere perfunctory application of the scheme would increase instead of diminish danger. Substitution of an iron for a copper rod is common but injudicious. Copper, being the best available conductor of electricity known, should always be employed;

and in regard to sectional area—with the extent of which, electrically, conductive power is proportional—that should not be less than half an inch.

PIER AND HARBOR WORKS IN THE ISLE OF MAN.

From "Engineering."

Before a constantly increasing intercourse with the outer world had enlarged the town of Douglas and increased the imports and exports of the Isle of Man, the old Red Pier, as it was called, subserved as a landing place all the requirements of that part of the island. In time, however, the want of greater harbor facilities and the absolute necessity for increased safety and accommodation for vessels, impressed itself very forcibly upon the inhabitants, and led to active steps being taken for the construction of a pier and landing place which should be adequate to the requirements of the large class of vessels, and more particularly the steamboats frequenting the island. A fine landing pier has been constructed and another is now in progress, which, when completed, will form a breakwater and landing place, and with the first one will constitute a harbor affording ample facilities for landing and embarking, at the same time providing safe anchorage for vessels visiting that part of the coast. The pier which has recently been completed is named the Queen's Pier. The second is known as the Battery Pier.

Taking the completed work first, we may observe that the practical object sought by its erection was to secure, at low-water spring tides, such a depth of water as would enable steam packets and other vessels going into Douglas to land their passengers without having to resort to the objectionable aid of small boats. Sir John Coode was applied to for designs for the work, which were approved, and the pier sanctioned in February, 1867, the works being commenced in the April following.

The work may be regarded as consisting of two portions; the inner length or approach, and the pier proper. The approach commences at the east end of a roadway known as Bath-place, and extends 750 ft. along the crest of a rocky ledge known as the Pollock Rocks, passing over a rock called the Craig Kirk, which formerly stood at the low-water edge, but is now incorporated in the work. At this point the pier proper commences and runs in a south-easterly direction for a distance of 400 ft., making the total length of the structure 1,150 ft. The depth of water along the pier is from 6 to 18 ft. at low water of ordinary spring tides, the range of those tides being 21 ft. The total height of the pier from foundation to coping at the south-eastern or seaward extremity is 52 ft. On each side of the pier is a footway 10 ft. in width, and between these is a carriage way 30 ft. wide, thus giving a total width of 50 ft. at the top. On either side of the pier are three flights of landing steps 7 ft. wide, the two flights nearest the shore end reaching to low water of spring tides for the accommodation of small boats as well as for steamers. A neat iron railing extends throughout the whole length of the pier on either side, and there are 18 gas lamps placed at intervals along the footways. At the outer end of the pier there is a substantial cast-iron pillar of ornamental design, surmounted by a lantern carrying a green light, which is exhibited from sunset to sunrise. The light is intensified by a Fresnel dioptric annular lens; it is placed at a height of 47 ft. above the mean level of the sea, and the beam extends over 23 points of the compass, or an arc of 260 deg.

The chief feature which distinguishes this structure from all others of its class is the material of which it is built, which is ashlar work entirely in concrete. It is the first example of the kind in this or any other country, as far as we are aware. The main or outer walls, the cross walls, steps and copings consist entirely of compound blocks, weighing from 5 to 10 tons each, and formed in moulds either as concrete or rubble masonry, but in all cases set in the work as square ashlars aggregated by means of Portland cement of the highest quality procurable. The surface and footways of the pier are also of Portland cement concrete. The pockets formed by the main and cross walls are filled in with dry rubble hearting. The cost of the work has been £46,400, and the quantity of concrete masonry in it amounts to 44,000 tons, or 675,000 cubic ft. The structure, we need hardly say, is

of the most substantial character, and is highly creditable.

The second portion of the work—the Battery Pier—extends from the land at Douglas Head nearly at a right angle with the Queen's Pier. It derived its name from the proximity of its position at the shore end to the old battery on Douglas Head. This work runs seaward in an E.N.E. direction, and when completed will be 550 ft. long, and will cost about £54,000. The object of this pier is to form an arm or wing wall corresponding in a measure to that formed by the Queen's Pier, the two enclosing an extensive sheltered water area. A pier had already been built for a portion of the distance to be traversed by the new structure, but which was washed away about seven years since. The Battery Pier is being constructed in a precisely similar manner to the Queen's Pier. The face blocks in the walls measure 8 ft. 8 in. × 4 ft. 4 in. × 3 ft. 4 in., and weigh 8 tons each. They are laid in alternate courses of header and stretcher. The pockets formed by the main and cross walls are filled in with dry rubble hearting. In those portions of the work where the rock was used as a foundation to build upon, the blocks of concrete were built *in situ*, below the level of spring tides. Some of these blocks weigh 220 tons each, and reach to the level of low water, the work being carried up above that point with the smaller blocks referred to. The walls are to be protected by American elm fenders and an elm kerbing. At the pier head there will be a cast-iron lighthouse of octagonal form and Gothic design, the light being 30 ft. above high-water spring tides. The work was sanctioned in July, 1869, since which time an approach road, 1,100 ft. long, a depôt and a work-yard have been made. The foundation stone of the Battery Pier was laid when the Queen's Pier was opened, and it is expected to be completed in the early part of 1873. The pier is being constructed from Sir John Coode's designs, and the works are carried out by him without the intervention of a contractor. Although the length of the portion authorized is 550 ft., this is not the whole extent of the work. To complete the harbor an extension of this pier is required, and will doubtless be carried out. It will be a continuation of the present pier, about 450 ft. in length, and running in a north-easterly direction, thus forming an angle of about 150 deg. with the landward portion of the pier. It will be 50 ft. wide at the quay level, including the parapet wall, which is to be 10 ft. thick. The top of the parapet will be 41 ft. above low water. The pier is being so constructed as to allow steam vessels to run alongside at low water of the lowest spring tides.

ROCK-BORING MACHINES.

From the "Mining Journal."

Mr. M. A. Pericolet, engineer of mines in Anzon, publishes some interesting facts relative to the operation of the Sachs Rock-Drill, at Moresnet, from which we take the following:

The work to be done consisted in the completion of a gallery, 15 sq. ft. in section and 416 ft. long. The materials penetrated were schistous grauwacke and a bed of quartz ore, all rocks of great hardness. Through this an advance of 223 ft. was made in six months. The drills are worked by compressed air. The compressor is installed on the surface, and driven by a water-wheel of 6-horse power, by which the air is compressed in a reservoir. The main connecting the reservoir with the drill is 872 ft. long, and the air is led from this main to the drill by an india-rubber pipe 1 15-16 in. diameter. The frame carrying the drills consists of a cage of wrought and cast iron supported on two longitudinal timber bearers, forming a frame, and rolling upon four wheels. The perforator acts by concussion. It is composed essentially of a gun-metal cylinder, in which is a piston and a forward piston rod of large diameter, leaving between it and the cylinder only an annular space of 15-16 or $\frac{7}{8}$ of an inch. At the back of the piston is a rod of small diameter. The larger piston-rod carries the cutting tool. The rear rod gives movement to a system of levers established at the back of the apparatus, and controlling the distribution of the air, producing the reciprocating motion of the cutter, and its rotation, as well as advancing the apparatus bodily in proportion to the depth of the hole cut. In operating these perforators the frame is brought almost up to the face to be drilled,

and wedged solidly in position. A foreman miner marks the points where the holes have to be drilled, and four workmen, charged with the apparatus, consisting of two perforators, place it in such a manner that the two cutters act on the points intended. This done, the piston is drawn back to the end of its stroke, and the cutter is keyed upon the forward rod; the apparatus is then advanced upon its frame until the diamond of the cutter touches the face of the rock. Connection is then made with the air main, and, the admission valve being opened, the piston is put in motion, and, until a depth of $\frac{3}{4}$ in. is attained, the rate of striking is very slow, and the direction of the cutter is carefully watched. The hole once commenced, and its direction being assured, the admission valve is put in full gear, and a speed of 200 or 300 blows a minute is obtained, a stream of water being directed against the hole. When necessary, a longer cutting tool is substituted, as the required depth is gradually obtained. Without shifting the apparatus, as many holes as are desired may be perforated. The drilling being completed, the four workmen in charge disconnect the rubber pipe, strike the wedges holding the apparatus, and remove the whole to a distance sufficient to save it from the debris of explosion. The following results have been obtained at Moresnet. To perforate 200 ft. by hand, 13½ months were required, giving an average speed of about 15 ft. a month. The mean advance of the machine was 37 ft. 3 in., or about 2½ times that achieved by hand labor. These results are very satisfactory. M. Pericolet calculates as follows the net cost per cube metre of rock broken down:

Miners' wages	£1	6	2½
Mechanics and fitters	0	2	10
Powder and fuse	0	1	8¾
Maintenance of the compression	0	0	3
	£1	11	1

Or about 10s. 6d. per cubic ft.

The cost per cube metre for hand labor was about £2 19s. The cost of first establishment was £1,816 for 12 perforators at Vieille Montagne. In the various German mining districts the Sachs drill is coming into very general favor. Some months ago it was successfully introduced at the great mine Stahlberg, of the Cologne Husen Company, and within a very short time it has gained the favor of the miners, since they see that their work is much alleviated, and that they are constantly supplied with fresh breathing air by it. The machine has been introduced here both for sinking and driving, and in a hard quartzose grauwacke it will bore a hole of 22 to 24 in. in depth in 7 to 8 min. of effective boring time, and require about as much time again for setting it up to begin a new one. The compressed air is of 28 to 30 lbs. per square inch, and its loss of pressure is almost imperceptible, though it is conducted through a 1½ in. pipe over 400 fathoms from the air-pumps to the machines. The same boring machine continues to give excellent results at the lead mines of the Meckernich Company, near Commern, in Rhineland, where a great cross-cut, for the use of underground locomotives, and the new Virginia shaft, are being excavated by its help. It is also to enter the great competition of rock-boring machines for the new Gothard tunnel, which will shortly take place at Goschemen, in Switzerland, under the direction of Mr. Herwig, the chief engineer of the Gothard tunnel.

THE STRENGTH OF BRICKWORK.

From "Engineering."

The torn and ragged keyless arches and baseless walls of our ruined abbeys, the partially demolished houses on the track of some new railway or road, and many other equally trite instances might be cited as standing evidence of the truth that good masonry or brickwork will resist with energy not only crushing, but breaking across, and tearing, twisting, or shearing asunder. No wonder, then, if the first element alone be included in the calculation, that many a brick structure whose fall has been prophesied refuses to acquiesce in the false laws of the prophet. The prophet's dictum might probably be justified by the result if full work were imposed upon the structure before sufficient time had been allowed for the full development of all the powers of the brickwork, but the experienced practical builder never loses sight of this condition, but by the use of cement in some places, and of props and supports in others, gives the brickwork the necessary temporary aid, and so insures success.

Hundreds of cases might be cited where the structure must necessarily have failed had not brickwork been capable of exerting considerable resistance to transverse strain. As a case in point, illustrative of the fact that a walk through the streets will afford all requisite data, reference may be made to a dwelling-house near Hammersmith Bridge, carried upon a series of very flat elliptical arches springing from piers about 12 ft. in height, and averaging only 18 in. sq. Any young engineering friend of the builder would no doubt have patronizingly predicted to him the fall of his work, for does not the line of thrust cut many yards outside the base of the angle piers where the two 14 in. arches meet at right angles; and is not the including of the line of thrust within the "middle third" of the thickness one of the necessary elements of stability? Many cases of this class are to be met with in small country towns, where the town hall is carried upon arches and piers of the preceding description in order to afford space for a market underneath. These buildings do not tumble down, and as country builders reproduce the type continually, it is by no lucky chance that they escape. The country builder is wiser than his critics; he does not aim at making an *arch* except in appearance, for he has no abutments, but he takes special care to put his work together in such a manner as to insure his getting a serviceable and perfectly reliable brick *beam*. There is another class of cases illustrative of the extent to which ordinary builders successfully avail themselves of the transverse strength of good brickwork, which may be suitably referred to here. As an example there may be taken the not infrequent case of a corner shop where the solid flank wall of the house is carried upon a rolled joist to admit of the shop front underneath being advanced beyond the general line of the building. It is easy enough to show that in many instances the weight of the wall and other load over the joist is in excess of its breaking weight, but yet no signs of weakness or distress are evidenced by the iron work, nor is there even any appreciable deflection of the joist, so why make it stronger, the builder may reasonably ask. Although the brick wall itself constitutes a brick beam to a great extent, if not entirely self-supporting, certain precautions are necessary to be taken during the progress of the work. Thus, in a recent case which came under our notice, the iron joist deflected to an undue extent, when some 10 ft. in height of the wall upon it had been run up, upon which the builder propped up the joist until, and for some time after, the completion of the wall to its full height of 35 ft., and subsequently removed the struts without inducing any appreciable increase in the sag of the joist. In short, a certain amount of time must be allowed, proportional to the stress to be sustained by the brickwork, in order to admit of the latter developing the necessary powers to resist transverse strain, or, in other words, to act as a beam.

The term "brick beam," though it may sound unfamiliar to many ears, is of no modern invention. A generation of engineers have almost passed away since the celebrated "Nine Elms" brick beam was tested and discussed by the engineers of the year 1837. This beam was in cross section in the form of an inverted ⊥, 4 ft. 9. in. deep by 2 ft. wide for the lower six courses of bricks, and by 1 ft. 7 in. wide for the remainder of the depth. At a span of 21 ft. 4 in. the breaking weight at the centre proved to be 22 tons 12 cwt., or including one-half of the weight of the beam, the bending stress taking effect at the centre was no less than 27 tons. It is necessary to note that several courses of hoop iron bond were worked into the lower courses of this beam, since Brunel attributed its high resistance to this cause, although the experimenters, Messrs. Francis and Hemans, judging from the nature of the fracture, were of opinion that the hoop iron had contributed little or nothing to the strength of the beam. Subsequent experiments have shown that the truth was to be found between these extremes, and that the hoop iron contributed just so much, and no more, additional strength as theory would indicate. In the case of the Nine Elms beam this would be a comparatively small amount, since the hoop iron was of no great section, and the relative elasticities of the materials are such that in no case could a large unit strain be imposed upon the iron in a compound beam of brickwork and iron until after the fracture of the brickwork had occurred.

Little progress appears to have been made in the investigation of the strength of brick beams for a period of 14 years subsequent to the date of the preceding experiment, in fact, until Messrs. Bazley's beam was tested at the Exhibition of 1851. The

beam in this instance was of much the same size as that tested at Nine Elms, the depth being 4 ft. 6 in., and the width at bottom and top 2 ft. 3 in. and 1 ft. 6 in. respectively; the bricks, however, were constructed hollow, with a thickness of $\frac{9}{10}$ths of an inch of clay. The breaking weight at the centre of the span of 21 ft. 4 in., including one-half the weight of the beam, was about 32 tons. This shows an increase of 5 tons as compared with its original model, the Nine Elms beam, or about the amount which might have been anticipated from the improvement in the quality of cement effected in the interval between the two experiments. In this instance, as in the previous one, hoop iron bond was introduced; hence, before these experiments can be used as data for ascertaining the transverse strength of brickwork, it will be necessary to collate them with others where no such bond was employed.

In order to reduce the several experiments to one standard for comparison, it will be convenient in all instances, to ascertain the value of the unit tensile strain in pounds per square inch, $f = \frac{M}{m}$; M being the moment of the stress, which for a weight at the centre of the beam will be $= \frac{W\,S}{4}$; and m the moment of resistance of the cross section, which for a rectangular form of cross section will be $= \frac{d^2\,b}{6}$. Hence, if the weight, W, be taken in pounds and the dimensions of the beam in feet, the value of the maximum unit tensile strain upon the brick beam will be:

$$f = \frac{W\,S}{96\,d^2\,b}$$

Applying this formula in the case of the two preceding experiments, the tensile resistance per square inch of the brickwork and hoop iron will be as follows:

Nine Elms beam..... $f = 290$ lbs. per sq. in.
Exhibition beam..... $f = 350$ " "

It will be necessary now to compare these values of f with those derived from experiments on brick beams, in which no hoop-iron bond was introduced, and also with the direct tensile resistance of cement and brickwork, as deduced from independent sets of experiments. By these means adequate data will be obtained to enable the probable strength of any brick beam to be predicted with a sufficient degree of accuracy to meet the engineer's or builder's requirements. The ordinary mode of experimenting upon the transverse strength of cement, or mortar and brickwork, is to carry out from a brick wall a cantilever of single bricks cemented together, and either to continue adding bricks to the end until fracture is effected by the weight of the cantilever itself, or to carry it out for a fixed distance, and then break the cantilever by the application of a load at the end. The depth of the beam in these instances may be taken as $8\frac{1}{2}$ in., the breadth $4\frac{1}{2}$ in., and if n be the number of bricks cemented together, the length of the cantilever may be taken as $3\,n$. Hence, if w be the weight in pounds suspended at the end of the cantilever, and $7\frac{1}{2}$ lbs. be the weight of a single brick, the resulting unit strain from the weight at the end, and from the weight of the cantilever itself, will be:

$$f = \frac{15\,n^2 + 4\,n\,w}{72}$$

Applying this formula, in the first instance, to a type example of General Pasley's experiments, which were carried out long previous to the construction of the Nine Elms beam, the case may be taken where the number of bricks cemented to the wall amounted to 31 in all, one brick having been added on each successive day until fracture occurred. Hence in this instance the value of f will be:

$$f = \frac{15 \times 31 \times 31}{72} = 200 \text{ lbs. per sq. in.}$$

Selecting, now, for comparison with the Nine Elms beam, some experiments of about the same date, carried out by Messrs. Aspden and Robins, the value of f, for the type examples cited below, would be as follows:

Bricks.				lb.		lb.
1. 38	cemented	together	broke with	14	at end f =..	330
2. 30	"	"	"	15	" f =..	210
3. 22	"	"	"	168	" f =..	310
4. 25	"	"	"	56	" f =..	210
5. 26	"	"	"	74	" f =..	247

In the same series of experiments, 16 bricks, cemented together, broke with a weight of 15 cwt. applied at the centre of 2 ft. 6 in. bearings; hence in this instance $f = 234$ lbs. In all the preceding cases Portland cement, with varying proportions of sand, was employed, but where Roman cement of an inferior quality was substituted, the value of f sank as low as 30 lbs.

Selecting in the same way, for comparison with the "Exhibition" beam, some experiments of the same year, by Messrs.

White, the value of f for one type case, where 16 bricks were cemented together, and tested with a weight of 370 lbs. applied at end, was 380 lbs.; and for another type case, where 20 bricks cemented together broke with a weight of 1,300 lbs. applied at the centre of 3 ft. 6½ in. bearing, the value of f was 255 lbs.

Many other experiments might be adduced, but as they would merely afford confirmatory evidence to the preceding, they may be dispensed with. It may be mentioned, in justification of this conclusion, that the value of f, as deduced by Weisbach, upon an entirely different basis to the preceding, varies from 180 lbs. to 340 lbs. per sq. in.

It will be necessary now to consider briefly the ultimate tensile resistance exhibited by brickwork under a direct pull, and not, as in the preceding experiments, through the indirect agency of a transverse stress. From the nature of the material under consideration, it may be anticipated that, practically, the direct tensile resistance, f_1, will be equal to f, although it is well known that in some other materials, such as wrought and cast iron, the value of f_1, is sometimes less than $\frac{1}{2}f$.

The tensile strength of a mass of brickwork will obviously be limited by the intensity of adhesion of the cement to the bricks in some instances, and by the intrinsic strength of the cement and bricks respectively in others. In new or green work the strength of the cement will govern that of the whole mass, but after the lapse of a certain period, varying with the nature of the cement, the bricks, if badly selected, will often prove the source of weakness. However inferior the bricks may be, the mass of brickwork must, nevertheless, if the cement be good, possess considerable tensile strength. In any cross section the area of the cement joints will amount approximately to ¼th of the entire sectional area; hence, if the bricks possessed absolutely no intrinsic strength, the average resistance per unit of area of the entire mass could not be less than ¼th of that of the cement employed.

General Pasley states the average adhesion of two bricks cemented together with Portland cement to be 5,000 lbs., or, say, $f_1 = 140$ lbs. per sq. in. Vicat takes the adhesion as equal to the tensile strength of the cementing material, and gives the following values to f_1, one year after mixture:

		lbs. per sq. in.
Good hydraulic lime	f_1	= 170
Ordinary " "	f_1	= 140 to 100
Rich lime	f_1	= 40
Good hydraulic mortar	f_1	= 140
Ordinary " "	f_1	= 85
Good common mortar	f_1	= 51
Bad " "	f_1	= 21

Roudelet cites 33 lbs. per sq. in. as the adhesion of common mortar to brickwork six months after mixture, and this conclusion is verified by the results of some experiments carried out by Mr. Robertson in the year 1858, when the adhesion of well-ground mortar, six months after mixture, was found to be as follows:

		lb.
Well-ground mortar and blue bricks	f_1	= 40
" " " grey stocks	f_1	= 36
" " " soft place	f_1	= 18

The inferior results obtained with the soft bricks were due to the water being taken up by the bricks, and consequently not being available for the formation of silicates.

In the same series of experiments the adhesion of cement to grey stock bricks at the end of one week and of one month respectively, after mixture, proved to be as follows:

		lb.
Quick setting cement, 1st week	f_1	= 23
" " " 4th "	f_1	= 30
Slow " " 1st "	f_1	= 15
" " " 4th "	f_1	= 59

The very exhaustive series of experiments carried out by Mr. Grant on Portland cement of the best quality afford valuable information as to the progressive increase in the strength of cement during the first year of its age. The average results of his experiments upon cement weighing 112 lbs. to the bushel, are fairly represented below for the proportions of cement and sand referred to:

Material.		One week.	One month.	Three months.	One Year
		lb.	lb.	lb.	lb.
1 cement to 2 sand	f_1	=23	55	113	205
1 " 1 "	f_1	=43	137	163	310
Net cement..	f_1	=200	300	390	480

With cement of the unusually great weight of 123 lbs. per bushel, the corresponding increase in strength at the early

stages was very noteworthy, as will be seen by the following tabulated results:

Material.	One Week.	One month.	Three months.	One Year
	lb.	lb.	lb.	lb.
1 cement to 1 sand	f_1=157	200	243	317
Net cement	f_1=365	415	470	545

With Roman and Medina cement the results obtained by Mr. Grant were very unsatisfactory, as will be seen from the following summary of about 500 experiments:

	1 week.	1 month.	3 months.	1 year.
Net cement f_1 =	42 to 106 lb.	93 to 168lb.	71 to 208lb.	93 to 300lb.

With an admixture of sand the results were so irregular as to render a record of them useless.

The preceding Tables epitomize the results of several thousands of experiments on the tensile strength of cement and mortar; it will, therefore, be unnecessary to adduce further evidence. At first sight the irregularity of the results attained, as regards the direct tensile strength of brickwork, may appear inconsistent when compared with the comparatively uniform value of the same resistance as deduced in the previously cited experiments upon transverse strength. If it be remembered, however, that in the case of the brick beams submitted to test, high class cement alone was used, the apparent discrepancies vanish, and it will be evident that, practically as well as theoretically, the values of f and f_1 may be taken as identical. If due consideration be given to the latter series of experiments, it will also be evident that the great strength of the Nine Elms and Exhibition brick beams was not, as suggested by Brunel, due almost wholly to the hoop-iron bond, but that, on the contrary, the introduction of the iron had, as asserted by the experimenters themselves, little to say to the question of resistance.

The variance in the results attained in both series of experiments might also be cited by some engineers as a sufficient justification of their habitual exclusion of the element of tensile resistance in any calculations referring to brickwork; although as a matter of fact, and as already shown, all engineers rely, though it may be unconsciously, upon this property of brickwork in the practical execution of their works. But this position is not tenable, since it may readily be shown that quite as wide a variance in the results is exhibited by brickwork under compression. Thus many hand-made, ill-burnt bricks will not bear a pressure equivalent to but 14 tons per sq. ft. without crumbling, whilst not very long ago one unprecedentedly strong machine-made brick by Clayton & Co. was found by Kirkaldy to sustain a pressure equivalent to no less than 323 tons per sq. ft—a variance quite as wide as any exhibited by brickwork under tensile strains. Many of the bricks supplied by the same makers for the Midland Railway and Thames Embankment contracts bore 95 tons per sq. ft., before cracking to any extent, 133 tons before cracking to a considerable extent, and 190 tons before crushing throughout.

Piers of compressed bricks 2 ft. 6 in. high by 8½ in. sq. were tested by Mr. Robertson and found to sustain 50 tons per sq. ft. when set in grey stone lime, and 200 tons, when set in Portland cement. Clarke found that the resistance to crushing of rather soft bricks set in cement averaged 34 tons per sq. ft., and many other experiments might be cited to show that this amount fairly represents the average resistance of ordinary stock bricks set in ordinary good mortar. Grant's experiments show the crushing resistance of bricks made of net Portland cement to be 243 tons per sq. ft. when 3 months old, and 385 tons when 9 months old, whilst with the addition of one part of sand the respective resistances were reduced to 160 tons and 292 tons, and with five parts of sand to 61 tons and 108 tons per sq. ft. Properly made concrete, consisting of one part of grey stone lime to six parts of ballast, is at least as strong under compression as good stock brickwork; and concrete made of one part of Portland cement to nine parts of unscreened ballast, has been found to possess ample transverse strength for fence walls and similar works.

Having thus briefly reviewed a small, though for the present purpose a sufficiently large, portion of the mass of information in existence bearing upon the strength of brickwork, a little space may usefully be devoted to the consideration of the practical inferences which may be drawn therefrom. In an early part of this paper it was premised that to an intelligent and thoughtful observer a mere walk through the streets, and an inspection of the buildings

erected or in progress, would suffice to prove that brickwork was possessed of many other valuable properties besides that of the simple power to resist a thrust. The evidence subsequently advanced has all tended to justify this conclusion, and if proper use be made of the data now at hand, in no case will theory and practice be found at variance. The speculative builder's apparently fatuous mistake in neglecting to put in a massive abutment wherever he introduces an arch, will be seen to be no mistake at all, but simply an unconscious adherence to theoretical principles, since as a matter of fact he is not dealing with an arch, but with a brick beam which gives no horizontal thrust, and requires no abutment. In the same manner, the firm belief entertained by most practical builders as to the sufficiency of almost any piece of iron joist that may come to hand to carry a brick wall of any height across openings of the size ordinarily met with in their practice, admits of scientific justification; whilst on the other hand the belief entertained by our typical young engineer fresh from King's College, that the bending action upon such a joist would be that due to the entire weight of the mass of super-imposed brickwork, can be shown to be utter and indefensible nonsense.

Probably few engineers would fail to smile at the suggestion that they should line their tunnels when carried through solid rock with 10 or 20, or whatever number of rings of brickwork might be found necessary to sustain the mass of rock overhead, upon the hypothesis that it is a fluid of uniform density pressing upon the brick arch or lining, like the water upon the internal flue of a Cornish boiler. Yet if the problem to be solved be to carry a brick wall or an arch —that is to say, to construct what is in effect merely a short length of tunnel through rock, for, as our experiments show, even comparatively green brickwork possesses greater transverse strength than many rocks—there are unfortunately not wanting many engineers in responsible positions who base their practice upon the assumption that the whole mass of the wall will press remorselessly foot by foot upon the arch; or who are so frightened at the powers they have conjured up, as to be led to assert that nothing less than massive wrought-iron girders could sustain the enormous pressure of the *fluid brick* wall with which, according to their unfortunate hypothesis, they have to deal.

The most glaring faults of a small country builder are venial in comparison with such blunders as these. He may at times select a piece of iron joist too light to carry his wall at the rate at which he is running it up, but since, as our experiments have shown, the strength of his mortar or cement will increase rapidly with age, his remedy will generally be found in propping up the joist temporarily until sufficient time has elapsed for the brickwork to develop the necessary powers for self-sustainment. As an illustration of the application of the data advanced in this paper, it may be useful to show that a lofty brick wall built entirely across a girder does not necessarily throw a greater strain upon the girder than a wall $\frac{1}{10}$th of the height, although in the face of the experiments already recorded this may appear a self-evident proposition.

Now h being the height of the wall, t its thickness, and S the span of the opening across which it is to be carried, all in feet, and f being the tensile resistance of the brickwork in pounds per square inch, then the transverse breaking weight of the wall as a beam in cwts. distributed over the entire span will be:

$$\text{B.W.} = \frac{12\, h^2\, t\, f}{\text{S}}$$

But the weight of the wall itself in cwts. distributed will be equal to S t h; hence, if the wall is to carry itself across any opening it must comply with the conditions of the equation:

$$7\,\text{S}^2 - 12\,hf = 0.$$

That is to say, the product of the height of wall into the tensile strength of the brickwork must always be a constant function of the square of the opening across which the wall has to carry itself. The span and tensile strength being given, the minimum height of the wall to be self-supporting will be:

$$h = \frac{7\,\text{S}^2}{12\,f}$$

If the height of the wall be less than that indicated by the above equation, an arch or a girder must necessarily be provided to carry some portion of the weight of the wall.

For any height not less than h, the portion of wall which will be self-sustaining will, since the weight is proportional to h, and the strength to h^2, be the fraction $\frac{h_1}{h}$ of the entire weight, and of course the fraction coming upon the arch or girder cannot

be less than $1-\frac{h^1}{h}$. Hence the greatest stress imposed upon the girder will obviously occur when $\left(1-\frac{h^1}{h}\right)h^1$ is a maximum, that is to say, when $h_1=\frac{1}{2}h$. Expressing h_1 in terms of h, the load upon the girder in terms of the entire weight of wall of the height h will be equal to $h_1-h_1^2$. This, as already shown, will have a maximum value when $h_1=\frac{1}{2}h$, and will then be equal to $\frac{1}{4}$; hence it appears that the height of wall producing the severest stress upon the girder will be equal to $\frac{7\,S^2}{24\,f}$, and that one half of the weight of the wall will then be self-supporting and one half require extraneous support.

It follows from this that the probable maximum stress induced upon a girder by a wall of *any* height will not exceed that resulting from a distributed load in cwts. equal to:

$$\tfrac{1}{2}\,\frac{7\,S^2}{24\,f}\,S\,t=\frac{S^3\,t}{7f}.$$

There is no pretence of theoretical exactness in the preceding deductions, indeed, in the absence of exact data on certain points, any attempt at refinement would have served only to obscure the broad truths which have been elicited in a simple form, and with a sufficient degree of accuracy for present purposes. The last deduced expression for the maximum stress upon a girder loaded with a solid brick wall is strongly at variance with the ordinary engineering hypothesis of a *fluid* brick wall, but singularly confirmatory of the speculative builder's ordinary and successful practice. The builder cares little or nothing what the height of his walls may be, but he has a wholesome horror of large openings. The preceding equation shows that except for very limited heights, the height of wall does not enter into the consideration at all, whilst the necessary strength of girder varies as the fourth power of the span. Again, the *rationale* of the builder's practice of temporarily supporting a beam which has proved to be rather too weak during the carrying up of a wall is now evident enough, since the stress upon the girder has been shown to vary inversely as the value of f, and that value, as the experiments cited show, increases rapidly as time is allowed for the mortar to set. Thus, assuming a 14 in. party wall, not supporting any floors, has to be carried across a 15 ft. opening, upon a 12 in. sq. balk of timber capable of supporting a distributed load of 173 cwt. without undue deflection, then sufficient time must be given, either by carrying the wall up slowly, or by supporting it during construction, for the mortar to develop a tensile strength in pounds per square inch equal to:

$$f=\frac{15^3\times 1\frac{1}{2}}{173\times 7}=3\tfrac{1}{4}\text{ lbs.}$$

The load of 173 cwt. upon the span of 15 ft. would be equivalent to that of a 14 in. wall 10 ft. in height; hence, the maximum stress upon this girder would occur when the wall was carried up to a height of 20 ft., whilst at a height of 40 ft. the wall with the given strain of $3\frac{1}{4}$ lbs. per sq. in. would be self-supporting.

The same result would, of course, have been obtained for the previous equation, in which the minimum height of wall capable of self-support was shown to be:

$$h=\frac{7\,S^3}{12\,f^2},$$

whence by substitution $h=40$ ft., as before.

If, as in practice is almost invariably the case, the wall be carried up during many successive days, the strength of the mass of brickwork will not be uniform, but be a maximum at the bottom of the wall, and gradually diminish towards the top. In such a case the value of f may be taken as one-half of the tensile strength developed in the mortar at the base of the wall; hence, in the case selected for illustration, sufficient time would have to be given for the tensile strength and frictional resistance of the brickwork and mortar to be equal to a stress of about $6\frac{1}{2}$ lbs. per sq. in., or the timber beam would show an undue deflection.

Many other illustrations might be given of the useful practical information deducible from the data advanced in this paper. When arches subjected to an equally distributed load are under consideration, the question of resistance to a bending moment is often of vital importance. Much surprise was expressed at the time at the comparatively enormous strength of some narrow strips of brick arches about 15 ft. span, and only $4\frac{1}{2}$ in. thick, tested by Mr. Fairbairn by the application of a concentrated load at the centre; but there were no just grounds for surprise, since the behavior of the arches was entirely and

simply consistent with the facts and theory referred to in the preceding investigation.

In conclusion, it may be well to reiterate the fact that the object of this paper has not been to dictate to the engineer any precise and absolute value which should attach to the inherent transverse strength of brickwork, but merely that he should never omit to include that element in his calculations. The engineer must in this, as in other instances, consider each case upon its own merits, and act accordingly, without attempting to save brain-work or to shirk responsibility at the expense of his clients' pockets. Where, as in problems of the nature now under consideration, the data are imperfect, and the effective supervision of the work during execution is of paramount importance, it is quite legitimate on the part of the engineer to provide for the maximum *possible*, as well as the maximum *probable* stress, which could take effect upon his structure. In the present case, if the arch or girder were proportioned to sustain the maximum *possible* stress of a "fluid" brick wall without exceeding the elastic limit of the material employed, and the maximum *probable* stress, according to the principles advanced in the preceding investigation, without exceeding one-fourth of the ultimate strength, the engineer would have no cause for anxiety, and yet would effect a considerable reduction in the cost of many of his works, as compared with others of a similar nature based upon the ordinary unsatisfactory and unscientific practice. It may be taken for granted that in the long run the interest of the engineer will prove identical with that of his client. A few carefully-matured designs well carried out, with a strict regard to economy, will bring more fame to the engineer than a cart-load of vain conceptions, since—in the incisive language of Lord Bacon, "Men mark the hits, but do not count the misses."

HEAT AND STEAM.

From "Engineering."

One or two propositions connected with heat and steam are even now not generally comprehended, notwithstanding all that Mayer, Rankine, Joule, and Clausius have done to instruct us; and a great deal of mental confusion on apparently simple truths connected with the formation and use of steam exists, not only among young engineers, but in the minds of men of considerable standing in the profession.

The chances are about ten to one that any mechanical or civil engineer in good practice, if asked why a steam engine works at all, would give a defective answer. To begin at the beginning, we would probably be told that the sun's rays stored up—to use popular phraseology—heat in old-world forests, which forests subsequently became coal-seams, the coal retaining all the beforementioned heat, and being ready to give it back to us when we want it. The coal so made we burn in a furnace, and so heat water in a boiler. This water is converted into steam, and this steam works the engine, giving out power which was stored up thousands or millions of years ago during the growth of the primeval forest. This train of argument, or, more properly, assertion, is imperfect and weak, inasmuch as it leaves absolutely untouched the phenomenon on which the whole sequence of events hangs. We shall, to simplify matters, suppose that the entire sun action theory is quite satisfactory, and we shall take up the question at the point where we burn coal under or in our boilers. Starting here, we ask our readers whether it has ever struck them as remarkable that heat should pass from the coal in the furnace to the water in the boiler. We know perfectly well what the answer will be. They will reply in the negative. Why should there be any difficulty in the matter? Now, it appears to us that not only is there a great deal of difficulty in the matter, but that this transmission of heat from one body to another constitutes one of the most remarkable phenomena of physical science, the importance of which is overlooked only because it is a thing of every-day occurrence with which all civilized mankind has been familiarized from its earliest childhood. Let us see what this transmission of heat so glibly talked about, really means in the case of fire and water. In order to narrow the field we are ranging as much as possible, we shall keep to the transmission of heat from coal to water, neglecting its transmis-

sion from coal to the iron of the boiler plate.

In a boiler of fair construction a pound of coal will convert 9 lbs. of water into steam. Each pound of this steam will represent an amount of energy or capacity for performing work equivalent to 746,666 foot-pounds, or for the whole 9 lbs., 6,720,000 foot-pounds. In other words, 1 lb. of coal has done as much work in evaporating 9 lbs. of water into 9 lbs. of steam as would lift 2,232 tons 10 ft. high. Now it is quite certain that the power thus stored up in the steam must have been actually done on the water. In other words, as much energy has been expended in breaking up the water into steam as would suffice to lift 2,232 tons 10 ft. high. Having got so far, we are met by the question, Why does the steam engine operate at all? In other words, why has the fuel in the furnace done this enormous amount of work on the water? It is certain that it can only have been done in one of three ways. Using once more popular phraseology for convenience, we may say that heat could only have got into the water either because it was forced in by some special action on the part of the fuel, or that it was absorbed from the fuel by some special action on the part of the water, or that it found its way in by a combined existence of force on the part of the fuel, and of absorption on the part of water. The popular theory is, that the water absorbs the heat, but popular theories are often erroneous, and this theory is especially so. It should be obvious that a body like water, which retains its cohesion with such tenacity that 746,666 foot-pounds of energy are required to convert about one pint of it into steam, cannot also manifest a power of absorbing the very agent which effects its disruption with such difficulty. The absorption theory must be absolutely rejected. The heat required for evaporation can only find its way in by main force; and nothing seems more startling than the fact that the volatile products of combustion in their rapid flight to the chimney should be able to perform the enormous duty implied by the act of evaporation. To the philosopher in his laboratory, familiar with the vibration theory as taught by Tyndall and others, and to the ordinary observer, there is nothing remarkable about the matter. The first understands pretty clearly the nature of the forces with which he is dealing, while the latter does not think at all. But we fancy that the phenomenon will appear very curious indeed to many of our readers who for the first time realize the fact that, so far from water absorbing heat as a sponge soaks up a liquid, a vast expenditure of energy is required to force even a single unit of heat into it.

Coming next to the popular theory of latent heat, we find that, although time and again has it been pointed out that the phrase "latent heat" is one of the most unfortunate that could possibly have been adopted, there are still scores of intelligent men who, led away by this expression, really believe that heat is stored up in steam in some way not recognizable by a thermometer. Now, as a matter of fact, there is no such thing as latent heat. Steam really contains comparatively little heat, certainly not more than an equal weight of water at the same temperature. When we speak of the "total heat in steam," we make use of a very inaccurate phrase, which we hope to see banished from the vocabulary of the engineer. The thermometer cannot recognize the existence of latent heat in steam, simply because there is no latent heat in it. What *is* stored up in steam is work, not heat; and, instead of speaking of the total heat of steam in degrees of the thermometer, we should speak of the total energy in steam in terms of British units. And here we may remark that it is open to question, whether, in the strict sense of the word, heat passes from burning fuel to the water in a boiler at all. It would probably be more correct to say that energy passes from the fuel to the water, and, by doing so, no erroneous impression could be conveyed. Until a temperature of 212 deg.—under atmospheric pressure—has been reached little or no work is done on the water in a boiler. The heat transmitted from the fuel remains as heat, or the work—if work it be—so transmitted appears in the water as heat; but the moment a temperature of 212 deg. has been reached, heat no more appears as heat in the boiler. On contact with the water it is transmuted into work—done in forcing the atoms of the liquid further apart in opposition to their desire to remain close together; and consequently, once ebullition commences, the augmentation of temperature ceases.

If we want the heat poured into the water in a boiler after a temperature of ebullition proper to the pressure has been reached, to appear as heat, we must con-

dense the steam without allowing it to do work, as by turning it into a vessel of cold water. Here—as it cannot separate the atoms of cold water far apart—the work will appear as heat. If, however, the work stored in the steam could separate the atoms, it would not reappear as heat—it would remain as energy. It is certain that, in steam in contact with water in a state of suspension, it is impossible to store up heat as heat, the water immediately transmuting the heat into work.

It is beyond our purpose to consider the practical bearing of the facts we have stated on steam engineering. We have endeavoured to put certain phenomena connected with heat and steam in a light which will, we feel certain, prove novel to not a few of our readers. The relations of heat and work ought to be well understood; but, owing probably to a certain confusion of ideas or of language—in not a a few cases of both—manifested by the writers of some of the text-books ordinarily read, they are not clearly comprehended. Our purpose has been served if we have succeeded in persuading such of our readers as heretofore held a different opinion, that water does not absorb heat of its own volition, but that heat has to be literally hammered into it with an enormous expenditure of labor, and that there is really no heat in steam except that which can be measured by the thermometer.

ANALYSIS WITH THE BLOW-PIPE.

From the "London Mining Journal."

So great is the importance of blow-pipe analysis to practical miners, especially when daily communication with a professional assayer is impracticable, that it is surprising that the use of the blow-pipe is not more generally learned by all who have any intention of pursuing such a course of technical education as should qualify them for the duties of the higher officers of mines, although it must be acknowledged that the works upon the subject are comparatively little known amongst the classes to whom they would be most useful. Since the issue of Sheridan Muspratt's translation of Plattner's book, almost the only work which has appeared in England is Mr. Blandford's translation of Scheerer's little treatise; and as this, although no doubt valuable of its kind, was better suited to refresh the memory of those who had already systematically studied the subject under a professor than to afford complete instruction itself, it has never become very generally known. Plattner has always been regarded as the standard authority, and as the progress made in all connected with analysis has been so rapid, that the lapse of more than 20 years afforded much opportunity for revision and extension, Muspratt's work has become obsolete, and a new translation was much wanted. This want has now been supplied. Within the last few years, a new edition of Plattner being required, Prof. Richter, of the Royal Saxon Mining Academy, or, as we are more accustomed to call it, the Freiberg Mining School, undertook the revision and enlargement of the work; and of this new edition Mr. H. B. Cornwall, M.A., M.E., of Columbia College School of Mines, New York, assisted by Mr. J. H. Caswell, M.A., has just completed a very excellent translation, with numerous emendations and additions,* which bring the information down to the present time.

The choice of a blow-pipe being of some importance to insure convenience to the operator, the first pages of the book contain descriptions of the pipe of the form proposed by Gahn, and approved by Berzelius; but as Black's form is, for all practical purposes, fully equal, and has the merit of being less costly, we think it may safely be substituted. To many, however, the use of the simple mouth blow-pipe is laborious, whatever instruction they have received as to the method of blowing from the cheeks, and therefore the author very properly gives some attention to the contrivances which have been devised for maintaining the flame without the help of the human lungs, remarking, with truth, that the caoutchouc bellows satisfies all requirements; and, with regard to fuel, he carefully describes the best form of lamp to be used when a wax candle is insufficient, and gas is not within reach. The blow-pipe and fuel being chosen,

* Plattner's "Manual of Qualitative and Quantitative Analysis with the Blow-pipe." From the last German edition, revised and enlarged by Prof. Th. Richter. Translated by Henry B. Cornwall, M.A., M. E., assisted by John H. Caswell, M.A. New York: D. Van Nostrand.

the blast and the flame are described, so that no difficulty is experienced in understanding the different nature of the various parts of the flame, explained immediately afterwards. Great care is likewise taken to describe and offer hints for the selection of the instruments, small vessels, and other objects used in blow-pipe analysis, so that the student is well prepared for the consideration of the practical portion of the work.

The second section of the book commences with a very valuable set of general rules, according to which the behavior of minerals and other substances before the blow-pipe can be determined, and a considerable proportion of their constituents discovered; throughout the section every particular is given which is necessary to prevent failure, and as Dana's mineral nomenclature has been followed, the work will be understood and valued wherever the English language is read. The tables showing the behavior of alkalies, earths, and metallic oxides alone and with reagents before the blow-pipe, are very clear and distinct; and the general rules for qualitative blow-pipe examinations, by which the separate constituents of compound substances can be detected by the partial aid of the wet process, are particularly lucid and complete. When the blow-pipe is used for determining the precise mineral under examination, and not merely for ascertaining the presence or otherwise of some given metallic or other chemical agent, the arrangement followed in this section of the book will be especially valuable, since under each element an account is given of its occurrence in the mineral kingdom, so that the presence of barium being indicated the blow-pipist can at once refer to the list of the principal minerals wherein that element occurs, and readily decide upon the requisite further tests to determine it. Again, the arrangements of the elements to be examined for is well calculated to facilitate reference—the alkalies and earths, the metals and their oxides, and non-metallic elements and acids being treated of in separate classes—a vast improvement on the alphabetical system, which is too often followed in works of reference. The section also contains a very useful series of examples which will enable the student to acquire experience in the readiest methods of dealing with salts, or similar combinations, of silicates, aluminates, metallic oxides, sulphides, selenides, arsenides, or of alloys, after having judged, by the general appearance, to which class the substance to be examined belongs.

In quantitative analysis by the blow-pipe it will readily be understood that, since the experiment is performed with only about 1½ grain of mineral (the assay centner being by common consent fixed at 100 milligr.), the amount of metal extracted is extremely small, so small indeed that it is almost impossible to weigh the resulting button, and to overcome the difficulty Harkort conceived the idea of measuring the buttons instead of weighing them. This idea he executed so well that it is possible to determine with sufficient accuracy the proportion of silver in an ore, mineral, etc., even when it contains less than 0.0033 per cent., or 0.96 oz. in a ton of ore. Harkort's scale is founded on the principle that the weights of the metallic spheres are proportional to the cubes of their diameters, and that these diameters can be accurately compared together by means of two fine convergent lines between which the spheres are laid. But, although accurate results are possible with this scale, extreme delicacy of manipulation is necessary, and to remove the difficulty which thus arises in the measurement, several beautiful litle instruments have been devised. Those of Rueger and Kleritz are described and illustrated by Prof. Cornwall, and as Kleritz has also corrected the slight inaccuracy resulting from the adoption of the principle upon which Harkort's scale is based, greater accuracy than is now obtainable need scarcely be desired. The value of such instruments as these will be at once appreciated by quantitative blow-pipists.

With regard to the formulæ of the silicates we notice that SiO^2 has been substituted for SiO^3 throughout the book, and that amongst the various additions made is one explaining a quantitative assay for mercury; this assay, which is essentially the same as that proposed by Domeyko, is very simple and exact. A glass tube about 3 lines in diameter, and 7 or 8 in. long, of not too thin glass, is bent at about 2 in. from the end to an angle of about 120 deg., and closed at one, the shorter, end, leaving the shorter arm 1½ to 2 in. long. The tube is thoroughly dried, and then from 500 to 3,000 milligr. of finely powdered ore, according to its richness, intimately mixed with 5 to 10 grm. of litharge, is introduced into it. The lower end is gradually heated over the

spirit lamp until the whole mass is melted and the glass begins to soften. The moisture that may be present condenses in the middle of the tube, while the mercury will settle as a thin film, sometimes scarcely perceptible, upon the sides of the glass. When all the mercury has been sublimed the tube is carefully heated, so as to concentrate the mercury as much as possible to a ring near the elbow; the tube is then allowed to cool, cut off with a file close to the ring, and the mercury then brushed together to one drop, and transferred to a weighed capsule. In this way 0.05 per cent. of mercury can be very readily determined, and the nature of the gangue has no influence upon the result. The excess of litharge serves not only to oxidize the sulphur and silenium, but also to remove the arsenic antimony and bitumen so frequently found in ores of mercury, and the resulting metal is so pure that it can be very easily and perfectly united into one drop.

The work, then, it will be observed, although published as a translation of Plattner, is really in advance of it in point of time and completeness, for whilst the last German edition is nearly seven years old, the translation extends to the present time, and as Prof. Cornwall has had the advantage of the co-operation of Professors Richter and Egleston, no fear need be entertained that there is any want of homogeneity in the work, or that any important advance made in Europe or America has escaped record. The classification and general treatment of the subject adopted by Plattner have been certified by Muspratt, Richter, and others of great experience in teaching, to be almost incapable of improvement, and as Professor Cornwall has combined with these merits that of giving the latest discoveries, it would be scarcely possible to place a more valuable and reliable volume on the subject in the hands of the student.

ON THE EXPANSION OF WATER.*

By MR. ALEX. MORTON.

From "The Engineer."

The expansion of water having received but little attention from modern writers and experimenters in Britain, and as a study of the subject necessitates recourse to foreign publications, widely spread and often difficult to obtain, the writer has been led to lay before you the results of his investigations and references, believing that the subject is one of the very first importance.

For a number of years past he has collected all the important experiments he could discover, as well as the writings of many philosophers of authority, and from a selection of the most modern, and those he considers the most trustworthy, he now lays before you the results of their determinations.

¶In a paper by Professor Miller, in 1856, "On the Standard Pound," Hällstrum and Muncke's observations have been thrown aside on account of certain sources of error pointed out by M. Despretz; and on considering carefully the observations of Despretz, Pierre, Kopp, Stampfer, and Plucker and Geisler, and after making the necessary corrections in accordance with the observations of M. Regnault, he relies exclusively on those corrected observations of Despretz, Pierre, and Kopp, believing that the mean of all three will approximate more nearly to the truth than any one of them taken by itself. Since Miller's paper was read many valuable additions and observations have been made by M. Hagen, M. Matthiessen, M. Rossetti, and others. In 1855 Hagen† used the method of Stampfer for his observations, which consists in weighing a metal, the expansion of which has been previously ascertained, in water at different temperatures. In 1866 Matthiessen‡ adopted the weighing method also, but instead of using a metal he weighed a piece of glass cut from rods, upon which he had made many and varied experiments at and through nearly every grade of temperature, from maximum density to the boiling point, to ascertain exactly the cubical expansion of that kind of glass. The glass piece cut from the rod was highly polished, and suspended by a

* Institution of Engineers and Shipbuilders in Scotland.

† Abdhandlungen d. K. Akad de Wissench zu Berlin, 1855.

‡ Philosophical Transactions of the Royal Society of London, vol. clv., 1866.

very fine platinum wire, hanging from a delicate balance placed in a glass case, so that the currents of air might not affect the different weighings. His weights, thermometers, and adjusting screw were from time to time adjusted with the Kew standard, and every care taken to obtain correct indications. To check his observations on the dilatation of water he weighed pure mercury in the water near and at the boiling point, and found it to coincide almost exactly with that obtained and published by Regnault. In 1866 M. Rossetti§ adopted the method of Despretz, Pierre, and Kopp; that is, by using dilatometers surrounded with a liquid whose temperature can be varied at will. When the surrounding medium has been maintained for a sufficient period of time at a constant temperature, and continually agitated so as to be uniform, the rise of the distilled water contained in the dilatometer is noted for such ascertained temperature. His first series of observations extended from the freezing point to 50 deg. Cent., or 122 deg. Fah.; and with a view to defining the maximum density he had the counsel of M. Regnault, and the use of his laboratory for determining the cubical dilatations of his instruments; the weight of mercury was defined by the exact balance of the "College de France," and his thermometers were constructed by the celebrated maker Fastré, and compared with Regnault's standard thermometers. The different apparatus, their position during the experiments, and the manner of procedure are very carefully described in an extract by M. Feltz.§ The temperature of maximum density arrived at by this series of observations is 4 deg. .07 Cent., or 39.326 Fah.

As his first determinations only extended to 50 deg. Cent., he resumed his experiments in 1868; ‖ and the result of his second memoir extends from −4 deg. Cent. *below* the freezing point, to the boiling temperature. The care with which his instruments were made and tested, and his own knowledge as an experimenter, coupled with the opinions of others qualified to judge of the necessary corrections on the labors of previous experimenters, his determinations should have a high value set upon them; but, like Professor Miller, he prefers taking the mean result of many high authorities' observations, instead of relying wholly on his own observations. In the second memoir the maximum density of water is stated at 4.04 deg. Cent., but again he sums up the united determinations of eight notable philosophers, and adopts the mean, which is 4 deg. Cent. or 39.2 Fah.; and this is exactly the temperature fixed by Despretz. Every experimenter since Despretz (1839), including Matthiessen and Rossetti, considers his observations, their regularity and defined amount at all temperatures, of the highest value. Now, a formula which would indicate the curve, showing the dilatation of a volume of distilled water, has been published by nearly every investigator of the subject; but to trace the curve from maximum density to the boiling temperature, with any degree of accuracy, two or more series of constants had to be adopted. Kopp, Pierre, and Matthiessen state their inability to discover a simple formula which would include that range. The formula given by M. Rossetti very well fulfils the conditions, but as some of the powers necessitate additional fractions of powers, and also as some of the terms have to be subtracted from the others, they cannot be termed simple formulæ; moreover, at temperatures considerably above the boiling point, in many formulæ, including Rossetti's, the minus term becomes greater than the plus term from which it has to be subtracted, and is consequently useless without renewed constants.

After gathering all the information that could be obtained on the subject, the writer has adopted a simple formula which fulfils all the conditions, and agrees so nearly with the mean determinations of others, that he has been led to advance it for your consideration.

The third column of Table I. has been extracted from Professor Miller's paper "On the Standard Pound," before referred to, and gives the mean values of Pierre, Despretz, and Kopp's observations corrected by himself.

The fourth column gives the deductions by the new formula, so that they may be readily compared. It will be observed that the greatest difference is about 0.00001. Table II. (see page 439) has been extracted from M. Rossetti's second memoir, and includes the observations of Kopp, Pierre, Despretz, Hagen, Matthiessen, Rossetti, Weidner, and Kremers, and the mean value of all these together has been taken by him as the nearest approximation to the exact di-

§ Annales de Chimie, 4 serie, tom. 10, 1867.
‖ Annales de Chimie, 4 serie, tom. 17, 1869.

latation of pure distilled water, and is given in the eleventh column. The twelfth column gives the deductions by the formula under consideration. It may be mentioned that those observations marked by an asterisk were discarded by Rossetti as evidently wrong.

TABLE I.

Temperature Cent.	Temperature Fahr.	Mean of Despretz, Pierre and Kopp's experiments.	By Formula.
3.945	39.1	1.000000	1.000000
5	41.0	1.000008	1.000009
6	42.8	1.000032	1.000033
7	44.6	1.000070	1.000071
8	46.4	1.000121	1.000123
9	48.2	1.000186	1.000188
10	50.0	1.000265	1.000267
11	51.8	1.000356	1.000359
12	53.6	1.000463	1.000464
13	55.4	1.000578	1.000581
14	57.2	1.000708	1.000710
15	59.0	1.0 0855	1.000852
16	60.8	1.001005	1.001005
17	62.6	1.001176	1.001170
18	64.4	1.001353	1.001346
19	66.2	1.001541	1 001534
20	68.0	1.001743	1.001732
21	69.8	1.001952	1.001941
22	71.6	1.002169	1 002161
23	73.4	1.002394	1.002391
24	75.2	1.002642	1.002631
25	77.0	1.002880	1.002881

To depart a little from the subject: some thirteen or fourteen years ago the writer was engaged with some experiments on the loss of heat by suddenly expanding steam, and at that time gave this institution his views on the subject. In that paper (Volume I. of the Transactions of this institution, page 103), he stated that "Steam when suddenly expanded extracts heat from surrounding bodies, and, from the experiments which I have adduced as proof of this phenomenon, it would appear to demand an exact equivalent of heat for the increase of its own motion."

No attempt was then made to define the amount, but Messrs. Cazin and Hirn have since instituted an elaborate series of experiments on this subject, with a view to determining the amount of heat; and the full descriptions of their method, and the determinations therefrom, have from time to time appeared in the different volumes of the "Annales de Chimie," and the result of their labors proves beyond doubt that suddenly expanded steam, at ordinary temperatures, loses heat by what they term internal work, *i. e.*, the work is overcoming the viscosity of inherent forces which appear to resist the expansion of its own body.

To return to our subject, Mr. Hirn* very carefully prepared a thermometric apparatus, by which he could determine the expansion of water at temperatures *above* the boiling point, with a view to defining the *amount* of heat necessary to overcome its own inherent forces, which is also termed internal work, and gives the results and his determinations up to 200 deg. Cent., or 392 deg. Fah., although the actual experiments only extended to about 182 deg. Cent., or 359.6 Fah.; but from a formula of interpolation, the dilatations are given in Table III., column third.

TABLE III.

Temperature Centigrade.	Temperature Fahrenheit.	Interpolated by M. Hirn from his experiments.	By Formula.
100	212	1.04315	1.04313
120	248	1.05992	1.05992
140	284	1.07949	1.07932
160	320	1.10149	1.10153
180	356	1.12678	1.12678
200	392	1.15899	1.15532

Those experiments by Hirn are the only observations *above* the boiling temperature that the writer has been enabled to trace, and therefore he must rely on them solely in comparing the deductions by the new formula with them, and with the exception of that at 200 deg. Cent., which has only been interpolated from a formula constructed by himself to trace the curve of dilatation, the lower observed temperatures and the formula very nearly agree. M. Hirn speaks highly of the observations of Despretz at temperatures below the boiling point; in fact, he has chosen these determinations to measure the capacity of his experimental apparatus. Many of the most eminent philosophers have been attracted by this subject, believing that a thorough notion of the exact laws by which water expands by heat cannot but lead to more correct notions regarding (steam) the vapor of water, and the vapors of other volatile liquids, as well as forming an exact relative measure for the determinations of the properties of other bodies. Dr. Andrews' invaluable experiments on the "Continuity of the

* Annales de Chimie, 4 serie, 1869.

TABLE II.

Temperature Centigrade.	Temperature Fahrenheit.	Kopp. 1847.	Is Pierre. 1845-52.	Despretz. 1839.	Hagen. 1865.	Matthiessen. 1866.	Rosetti. 1866.	Rosetti. 1868.	Weidner. 1866.	Mean values.	By Formula.
-10	14.0	....	1.201804	....	....	....	....	....	1.001904	1.001854	....
- 8	17.6	....	1.001272	1.001373	....	....	....	....	1.001346	1.001330	....
- 6	21.2	....	1.000866	1.000918	....	....	....	....	1.000893	1.000892	....
- 4	24.8	....	1.000557	1.000562	....	....	....	1.000516	1.000549	1.000546	1.000521
- 2	28.4	....	1.000317	1.000308	....	....	....	1.000296	1.000302	1.000308	1.000300
0	32.0	1.000123	1.000119	1.000137	1.000127	....	1.000134	1.000136	1.000137	1.000130	1.000130
1	33.8	1.000070	1.000065	1.000073	1.000069	....	1.000073	1.000075	1.000081	1.000072	1.000074
2	35.6	1.000031	1.000028	1.000033	1.000029	....	1.000033	1.000032	1.000040	1.000032	1.000034
3	37.4	1.000008	1.000007	1.000008	1.000006	....	1.000008	1.000008	1.000014	1.000008	1.000009
4	39.2	1.000000	1.000001	1.000000	1.000001	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
5	41.0	1.000006	1.000007	1.000038	1.000010	1.000006	1.000006	1.000006	....	1.000008	1.000009
6	42.8	1.100026	1.000034	1.000031	1.000034	1.000028	1.000027	1.000029	....	1.000030	1.000033
7	44.6	1.000061	1.000072	1.000071	1.000072	1.000066	1.000062	1.000058	....	1.000066	1.000071
8	46.4	1.000109	1.000123	1.000122	1.000125	1.000119	1.000109	1.000106	....	1.000116	1.000123
10	50.0	1.000247	1.000267	1.000268	1.000269	1.000271	1.000250	1.000246	....	1.000260	1.000267
12	53.6	1.000437	1.000461	1.000472	1.000464	1.000479	1.000450	1.000443	....	1.000458	1.000464
14	57.2	1.000679	1.000707	1.000715	1.000709	1.000742	1.000700	1.000691	....	1.000706	1.000710
16	60.8	1.000969	1.000998	1.001021	1.001001	1.001054	1.000990	1.000992	....	1.001004	1.001005
18	64.4	1.001307	1.001331	1.001390	1.001339	1.001412	1.001350	1.001346	....	1.001354	1.001346
20	68.0	1.001690	1.001713	1.001790	1.001721	1.001814	1.001750	1.001742	....	1.001746	1.001732
24	75.2	1.002589	1.002584	1.002710	1.002612	1.002731	1.002660	1.002620	....	1.002644	1.002631
28	82.4	1.003689	1.003613	1.003741	1.003666	1.003780	1.003700	1.003661	....	1.003681	1.003690
32	89.6	1.004816	1.004804	1.004940	1.004872	1.004981	1.004870	1.004889	....	1.004874	1.004899
36	96.8	1.006172	1.006142	1.006240	1.006223	1.006261	1.006190	1.006275	....	1.006215	1.006249
40	104	1.007682	1.007682	1.007730	1.007711	1.007730	1.007690	1.007738	....	1.007695	1.007733
45	113	1.009665	1.009683	1.009850*	1.009756	1.009751	1.009710	1.009708	....	1.009712	1.009765
50	122	1.011891	1.011936	1.012050	1.011994	1.011969	1.011841	1.011907	....	1.011941	1.011983
									Kremers.		
55	131	1.014225	1.014480	1.014450	1.014415	1.014376	....	1.014307	1861.	1.014375	1.014379
60	140	1.016715	1.017232*	1.016980	1.017009	1.016964	....	1.016867	1.016988	1.016919	1.016945
65	149	1.019428	1.020068*	1.019670	1.019764	1.019724	....	1.019602	....	1.019636	1.019675
70	158	1.022372	1.023059*	1.022550	1.022675	1.022648	....	1.022529	....	1.022555	1.022565
75	167	1.025672	1.026200*	1.025620	1.025734	1.025727	....	1.025615	....	1.025674	1.025610
80	176	1.028708	1.029483*	1.028850	1.028933	1.028953	....	1.028836	1.028958	1.028869	1.028870
85	185	1.032021	1.032892*	1.032250	1.032661	1.032318	....	1.032211	....	1.032212	1.032162
90	194	1.035525	1.036415*	1.035660	1.035766	1.035813	....	1.035162	....	1.035675	1.035666
95	203	1.039222	1.040043*	1.039250	1.039287	1.039429	....	1.039298	....	1.039297	1.039322
100	212	1.043125	1.043773*	1.043150	1.042969	1.043159	....	1.043116	1.043100	1.043130	1.043130
Temperature Centigrade of maximum density		4°.08	3°.86	4°.00	3°.87	4°.00	4°.07	4°.04	4°.00	4°.00	4°.0 Cent., or 39.2 Fah.

Gases"* leads to the notion of only one state, and what may be said of the gas or vapor of any liquid may also be said of the liquid itself, the difference being merely in degree.

The following formula was adopted from a study of a great number of formulæ, and the deductions therefrom compared with the most recent observations up to the boiling temperature, and, as it gave very exact deductions of the mean values through that range, the writer was afterwards pleased to find that the formula, with the same constants, also included the observations of Hirn, which extend nearly as far above the boiling temperature as the other experiments extend above that of maximum density. There are but three constants, and the logarithm of the temperature t, multiplied by two, gives the second multiplier, and that multiplied by two again gives the third multiplier, consequently it becomes a very simple formula, and a number of deductions at different temperatures may easily be computed in as many minutes; moreover, it is the only formula which includes the whole range, and agrees much more nearly with the mean of all the observations than any two experiments when compared with each other.

The constants of the formula have been arranged for Fah. degrees, with the absolute temperature of 461.2 deg. Fah., and the maximum density of pure distilled water 39.2 Fah.

FORMULA.

$$V = 1.0 \times \frac{a\,t + b\,t^2 + c\,t^3}{T^2}$$

T, the absolute temperature measured from 461.2 deg. Fah. below ordinary zero.

t, the temperature measured from that of maximum density, 39.2 deg. Fah.

V, the volume of water, that at maximum density being equal to 1.000000.

CONSTANTS.

$a. = 0.2863$	Logarithm $\overline{1}.4568213$
$b. = 0.5726$	$\overline{1}.7578513$
$c. = 0.0000026913$	$\overline{6}.4299621$

THE Iron Mountain Railroad Company are about to commence the erection of a large rolling mill on the banks of the Mississippi, immediately south of the river Des Peres. It will give employment to a large number of men, and will be first class in every respect.

* Philosophical Transactions, London, 1869.

REPORTS OF ENGINEERS' SOCIETIES.

THE AMERICAN PIG IRON MANUFACTURERS' ASSOCIATION assembled in Convention at Cleveland, Ohio, on June 27th. The attendance was large. Delegates were present from all sections, the West being most largely represented. The meeting was called to order by A. B. Stone, Esq., President of the Cleveland Rolling Mill Company, Vice-President of the Association.

The minutes of the meeting of organization held in New York, January, 1872, having been read, a communication was received from Mr. David Thomas, stating his inability from ill health and age to retain the position of President of the Association.

The resignation of Mr. Thomas was received with expressions of regret, and Mr. A. B. Stone, of Cleveland, elected to fill the vacancy.

The Constitution was amended, and officers elected. The following is a correct list:

President—A. B. Stone, Cleveland, Ohio.

Vice-Presidents—Eastern—Edward L. Cooper, New York; Mr. Firmstone, Pennsylvania; Henry McCormick, Pennsylvania. Western—Gen. Jas. Pierce, Pennsylvania; A. B. Cornell, Ohio; A. B. Meeker, Illinois.

Treasurer—Geo. W. Whitaker, Pa.

Managers and Executive Committee—A. B. Stone, Cleveland, O.; Edward L. Cooper, New York; Mr. Firmstone, Glendon, Pa.; Henry McCormick, Harrisburg, Pa.; General James Pierce, Sharpsville, Pa.; A. B. Cornell, Youngstown, O.; A. B. Meeker, Joliet, Ill.; James I. Bennett, Pittsburg, Pa.; O. W. Potter, Chicago, Ill.; J. H. Maxon, St. Louis, Mo.; Samuel Thomas, Catasauqua, Pa.; Geo. W. Whitaker, Bethlehem, Pa.; W. F. Bartlett, West Stockbridge, Mass.; Mr. Hall, St. Louis, Mo.

Secretary—Thos. Dunlap, Philadelphia. Office, 341 Walnut street, Philadelphia.

The morning was spent in discussing important topics of strictly trade interest. In the afternoon new members were elected, among which were leading companies of the Lake Superior region, many from Missouri, Indiana, Ohio, and Western Pennsylvania.

Communications were received, one from the Hanging Rock Iron Association, of Ohio, urging the universal adoption of the 2,000-pound ton in all iron transactions throughout the United States. In view of the importance of this subject, final action was suspended until the October meeting. The views of members as to the condition and prospects of the trade throughout the country were very freely exchanged. It is clear from the reports thus made that stocks of pig-metal were never lower; that the demand, instead of falling off, is increasing, and that the new furnace capacity now building is not of sufficient size to relieve the scarcity, even when in blast.

The Secretary read a report, reviewing the history of the trade since the advance here and abroad, and the condition of the furnace interest, and giving statistics of imports and domestic production. The report was ordered to be printed, together with the proceedings of the Convention, and sent to every furnace company in the United States.

It was determined to include, by the October meeting, every furnace in the United States as members. The Convention adjourned, to meet at

Pittsburg, on the third Wednesday in October, 1872.

THE "NEW-ENGLAND ASSOCIATION OF GAS ENGINEERS" held the semi-annual meeting at Newport, August 24. Representatives of a majority of the gas companies of New-England were present, together with Messrs. J. R. Thomas, W. R. Thomas, T. F. Rowland, and Dr. Smith, of Brooklyn, N. Y., and Prof. Stimpson, of Kansas University, as visitors.

Vice-President George Dwight, of Springfield, Mass. (the President being absent in Europe), occupied the chair.

The morning hour of the session was devoted to the consideration of the report of the committee upon the subject of the "sizes of pipes and supplies."

After discussing the report, Professor T. E. Stimpson, of Kansas University, presented and read a paper on the subject of "Gas-Burners,' which received the thanks of the Association, and was ordered to be printed for the use of the profession.

In the afternoon the Association, by invitation of Mr. T. F. Rowland, made an excursion down the bay on Mr. Aspinwall's splendid steam yacht, Day Dream, past Narragansett Pier, and as far out as Point Judith, which they examined carefully with good marine glasses. On returning to Newport, carriages were provided, and a drive occupied the rest of the day.

A meeting was held in the evening, when matters of general interest to gas engineers were discussed, and adjournment made to the annual meeting in February.

Thursday, the Association visited Narragansett Bay, and closed its labors and recreations with a clam-bake and a shore banquet.

SCIENCE FOR WORKING MEN.—A meeting was lately held at the house of the Society of Arts, London, for the inauguration of a new system of examinations for working men, whereby to encourage them to apply themselves to the study of elementary science in connection with their various trades.

For some years past there have been certain examinations supported by the Department of Science and Art, and certain others by the Society of Arts, by which it has been competent for an artisan of superior self-education to obtain such authoritative recognition as should enable him, diploma in hand, to seek advancement in his trade. In the course of what took place at this meeting, it appeared that in the Lancashire district, for example, a very considerable value has been attached to these examinations. The present project is, not to overthrow what has been already established in this form, and not even to interfere in any direct way with the work of the Science and Art Department; but, by the agency of the Society of Arts, to enlarge the field of study to which the principle shall be applied, and to aim, in short, at doing something towards the grand idea of providing for every artisan throughout the country such specific self-educational directions and such means of examination as shall enable him to learn the science of his trade as well as its rule-of-thumb, and to obtain successive recognitions of success, through which he shall be raised by express diploma to one degree after another of definite guild rank. It is suggested that there might be three grades of certificates, thus: "First, the elementary grade, or what may be termed the *workman's* certificate; secondly, the advanced, answering to the *foreman's* certificate; thirdly, honors, answering to the *manager's* certificate;" besides which, "each grade may further be subdivided into two classes—first and second." To bring the scheme to a bearing, the Council of the Society of Arts resolved "to hold their first Technological Examination in 1873, and to take up as the subjects the manufactures of Paper and Cotton."

IRON AND STEEL NOTES.

TEST OF AMERICAN IRON AND STEEL.—The American Society of Civil Engineers, at its recent session adopted a resolution, presented by Gen. Wm. Sooy Smith, providing for a committee of the Society to memorialize the U. S. Government, and urge it to appoint a commission to make a thorough set of tests of American iron and steel. The British Government, more than 20 years ago, appointed such a commission to make full tests of all forms and processes of iron manufacture, and deduce formulæ for the calculation of strength, which are still in use, not merely in Great Britain but in this country. Given any problem in regard to the qualities and strength of any form of iron manufacture,—even any of the numerous forms that have since been produced,—and the engineer simply turns to his hand-book containing formulæ in which the coefficient adopted by the British Commisson is used.

English and American irons differ from each other in certain general characteristics. American iron is softer than English. As respects resistance to tension strain, it is more ductile, tougher; while yielding more readily to immediate force, it will stand a greater ultimate strain; also, it undergoes vibration without crystallizing better than does English iron. English iron, being harder, stands a greater immediate tension strain, but yields to a less ultimate force, and crystallizes more readily under vibration. As respects compressive strain, the same general difference exists; it is believed that English cast iron, being harder, will, as the rule, resist greater compression than does ours.

Had the English formulæ been originally adapted to the determination of the strength of American products, the multiplication of new forms and qualities of iron in this country must long since have rendered them inapplicable in very many cases. There is a multitude of new forms and processes that have never been tested by any body of experts having authority to decide. Many experiments have indeed been made; but conducted by private parties, interested in the manufacture and use of iron and steel in one or another of its several varieties. They generally demonstrate the superiority for some special purpose of some particular process of manufacture or form of product. Moreover, these experiments are of little general value, inasmuch as they have never been collated and expressed in any formulæ applicable to our materials and processes generally. In regard to no other product, perhaps, do these considerations have so much force as in respect to Bessemer steel, which

has come into being since the British Commission made its tests and deduced its formulæ; while not merely does English Bessemer differ from American, but American varieties differ materially from one another. At the same time new processes of steel manufacture are constantly presented, and experts have no formulæ applicable to all, by which their value can be conclusively ascertained.

We need do no more than suggest the value in general which a long and full series of tests, thorough in each case and extending to all varieties of American iron and steel, would possess. Such facts would at once put us, in our iron manufactures, a century ahead of our present position. No single cause,—not all other causes combined, perhaps,—did so much to give England the high position she at once attained, or to maintain her undisturbed therein to the present time, as did the labors of her Commission. The value of such a series of tests of American iron, is thoroughly appreciated by the most eminent of our engineers and manufacturers. General Smith, about a year ago, addressed the present Secretary of War upon this matter, and he had no difficulty in securing the hearty co-operation in his memorial of six of the largest bridge-building establishments in the United States. The importance of the proposed tests is thoroughly appreciated by the members of the American Society of Civil Engineers; and now that this competent and influential body has taken the matter in hand, it would seem that Government cannot hesitate a moment—when once the subject is placed before it—to order and provide for the proposed tests. That the scheme will come before Government in a manner to command attention and respect, the character of the committee assures us. It consists of Gen. Wm. Sooy Smith, Chairman; Gens. Geo. B. McClellan and J. G. Barnard, Albert Fink, Esq., and James B. Eads, Esq. These eminent engineers have all expressed their approval of the plan, and accepted the appointment as members of the committee. General McClellan, in his letter of acceptance, only regrets that the Society did not embrace in the resolution, along with iron and steel, all other materials used in engineering processes and structures. This might readily be made the subject of additional instructions by the Society.—*Chicago Railway Review.*

Condensing Liquid Steel.—Though the process of hammering large ingots or heavy stocks of cast steel, when their interior part is still in a semi-fluid state, has been carried out effectually by Krupp of Essen, for more than twenty-five years, and Mr. Bessemer patented the operation of condensing semi-fluid cast steel by means of the hydraulic press as long ago as 1856, the importance of the process and its merits are not so appreciated that it would seem superfluous to direct the attention of metallurgical engineers towards practical investigations which were carefully made in that direction. It very often happens that a seemingly common-place invention merits the preference for its general usefulness before a more ingeniously conceived but unpractical idea, and the same may be said with reference to Krupp's and Bessemer's modes of proceeding, if compared with numerous other suggestions. The Bessemer press has even the great advantage before the steam hammer, that an apparatus of much less weight and cost will effect the solidification of a block of cast steel equally well and reduce the so-called honeycomb to its possible minimum. At the Austrian Steel Works, of Neuberg, in Styria, Chevalier Stummer, of Traunfels, has carried out a large series of of experiments in order to weld the interior particles of cast steel to each other as intimately as possible, and to prevent the honeycomb, which is an accumulation of fine pores, filled with elastic gases which are inclosed in the cooling metal. The principal result of these experiments is, that it is quite possible by exposing the semi-fluid metal to a great pressure to unite all the pores within a very limited space in the centre of the steel block. This fact is of the utmost importance in the manufacture of heavy steel ordnance, which is intended to bear the strain of very great charges, as in that case it is just the central part of the barrel which is bored out and the perfectly sound part of it left to form the wall of the gun. Thus a pressure of from 6 to 9 tons on the square inch will be sufficient to compress a red-hot steel ingot before its solidification, and give it an even structure throughout the whole mass, while the impact even of a very heavy steam hammer, like Krupp's 50-ton hammer, is principally spent on the outer part of the block, and the result will be the absorption of the power before it reaches the centre, and the exterior of the mass will be elongated and cause the tearing asunder of the central part. Only very heavy hammers or rams will effectually overcome the vis inertiæ, which a very heavy casting opposes to it.—*Engineering.*

The Danks Furnace.—At various works in the North of England, the construction of the Danks Furnace is being hurried on. A number of those furnaces will soon be at work, and practically tested on a large scale. At some places arrangements are being made for running the pig metal direct from the blast furnaces into the Danks puddling furnace, and it is thought that there is no reason why this plan should not be adopted in all cases.

Another New Puddling Furnace.—Another new rotary puddling furnace has been invented by Mr. Defty, a working man in Middlesbrough. His plan is to feed a long revolving chamber from a cupola, and run off constantly into ingots the puddled iron.

The Iron Trade in the North of England.—Buildings involving an immense outlay are now in course of erection at Stockton-upon-Tees, Middlesbrough, and other surrounding places in the North of England, in order to meet the requirements demanded by the extraordinary impetus which has been latterly given to the iron trade in that district. The quantity of pig iron produced in the neighborhood is at the rate of about 2,000,000 tons per annum, or a value of £10,000,000 at present prices. It will be admitted that this is something enormous both in quantity and value, and yet it is inadequate to the vast requirements of the trade, the demand being considerably in excess of what can possibly be produced. This being so, the various firms are endeavoring by every means to increase their productive powers by the erection of new blast furnaces. At the present time there are not less than

thirteen new furnaces in course of erection at Stockton and the immediate neighborhood, representing a value of £260,000, in addition to which several of the leading iron-masters are about to erect new and distinct works. Several new schemes represent a total capital of £1,018,000 about to be laid out in new works and buildings, in addition to other works now being carried out; and the total capital required for the completion of new works and the extension of established concerns within the next twelve months, as at present decided upon, is estimated at from £1,500,000 to £2,000,000.—*Builder.*

RAILWAY NOTES.

THE UNION RAILROAD COMPANY'S TUNNEL.—At the present time there are in course of construction, two tunnels beneath the city of Baltimore. That of the Baltimore and Potomac Railroad Company will be about 1½ miles long; the other, by the Union Railroad Company, has for its object the connection of all the roads with tide-water, and also to afford a passage around the city by steam-power, thus dispensing with the hauling of goods and passengers through the streets with horses.

The Union tunnel is being constructed under the bed of Hoffman street, which runs east and west. From façade to façade it is 3,400 ft. long. It is formed of a semicircular arch of five brick rings, and an invert of four bricks. In some places, where a good rock bottom exists, the invert is dispensed with.

About 450 men and 90 horses are engaged on the work. The material, which is mostly sand, is excavated to the whole depth of the cut; the arch is then built and the material replaced over it. The tunnel, with the exception of about 360 ft. which is being drifted, is worked in this way:

About one-third of the arch is finished at the present time (July 22d), and the whole tunnel is expected to be finished and ready for trains by next January.

The arch is being built in sections of 50 ft. in length, and these sections are being constructed at five or six points simultaneously.—*Franklin Journal.*

THE "COMPTOIR DES HOUILLES."—The imperfections in transport arising from the over traffic of the railroads, and the imperfections of the system of internal navigation, have for the moment been somewhat improved; but another and still more serious matter is anticipated, arising from the fact that the difference between the coal production and consumption in France is 50 per cent. In order to mitigate this double evil—the want of coal and the insufficiency of transport—30,000 wagons must be established, and an additional supply of 25,000,000 tons of coal must be found within the next five years. Now it is to be feared that neither England, nor Prussia, nor Belgium will be in a condition to furnish this quantity. It is from France itself, indeed, that the additional supply must be drawn.

It is upon this basis that a new company has just been established in Paris, called the "Comptoir des Houilles," which has for its object the development of the production of coal, and to establish means of cheap transport. This company, the establishment of which has been encouraged by many important manufacturers, will seek to obtain this double result by the following means. It will offer to the concessionaires of mines the means of developing their concessions; it will obtain capital for the working of mines which require assistance to develop their resources; and it will establish a special mineral rolling stock of its own for running over the existing railways. As a commencement, the company starts with £60,000 capital, but it has powers to increase to £400,000. The spirit of this undertaking is most praiseworthy, and it is one amongst many others now being established in France to assist and to develop her spirit of enterprise.

RAILWAY IN EGYPT.—The staff of surveyors and assistants, nearly thirty in number, taken out by Mr. John Fowler, C. E., to make a survey for a railway in the Valley of the Nile, have returned, after having successfully completed their work. The line surveyed is about 600 miles in length, and commences at Wady Kalfah, near the second cataract, and terminates at Khartum, where the Blue and the White Nile unite their waters, above the sixth cataract. For nearly three-fourths of its length the line will be on the edge of the Valley of the Nile, about three-fourths of a mile from the river, and constructed above the level of the periodical inundations. At the commencement of the great bend, between 18 deg. and 16 deg. north latitude, the railway will leave the valley, and proceed by a direct line across the desert of Bayuda to a point near the sixth cataract, whence it will follow the valley southwards to Khartum, the intended terminus for a time.

IMPROVED RAILWAY SERVICE TO SCOTLAND.—The Great Northern Railway, competing for the Scotch traffic, are about to put on a new service of trains by which London will for the first time be brought to 9¼ hours of the Scottish metropolis. These trains will carry first and second class passengers only, and leaving King's-cross at 10.0 A. M., will arrive in Edinburgh at 7.30 P. M., and Glasgow at 9.0 P. M., two hours earlier than by either of the competing routes. This important saving of time will be chiefly accomplished by a reduction in the number of stoppages, which it is intended to limit to Peterborough, Grantham, York, Newcastle, and Berwick-upon-Tweed. The new service will commence on Saturday, the 1st of June, and no interruption will occur in the existing ordinary traffic beyond a delay of ten minutes in the departure of the train now leaving King's-cross at 10 o'clock.

ENGINEERING STRUCTURES.

CANALS.—While the greater part of the inland carrying trade is being performed by railroads, and their development occupies the principal attention of parties engaged in that business, canals do not seem to be entirely forgotten. Ever since the commencement of the Suez canal we have been assured by eminent engineers (chiefly English) that it would be a failure. It has been suggested that these prophecies were not entirely dis-

interested, that under them lurked a desire on the part of the prophets to get a controlling interest in the stock of this "failure." Be this as it may, they have come to grief. The canal is not a failure. The report of M. Lesseps, the engineer, has lately been made, and from it appear the following facts: All the works on the canal proper have been finished, and the station or halting place of the Timsah lake has now been completed. This gives the company an internal port for ships to halt in, etc., of about fifty acres superficies and 26 ft. 2 in. deep. The bed of the canal for one hundred miles from Port Said to Suez has everywhere reached the depth of 27 ft. 2 in. Estimating from the experience of the past two years, the annual maintenance of the canal proper will cost 824,000 francs. For facing certain of the banks with stone and sundry repairs to the dykes and breakwaters at Suez, 56,400 francs; for the renewal of beacons and mooring posts, 27,600 francs. The facing of stone will be completed in a few years, and then that item will be no longer needed. Vessels of upwards of 2,000 tons burthen have passed through the canal at an average speed of about 8 miles per hour, and all apprehension of delay from any cause is entirely dissipated. The largest merchant vessels are now freighted to pass through the canal to Asia and the East Indies. A large fleet of new iron steamers are now building in England for this route.

A company has been formed in order to join Denmark to China by the canal. The Austrian Government has established a regular line between Trieste and India. Italy is going to increase the steam lines between Genoa and India, and also increase the general Italian traffic in the Indian seas. The Russian line between Odessa and the far East will definitely resume its voyages; and Spain is in constant communication with the Philippine islands, through this artery, by a mercantile fleet carrying the Spanish flag. In view of these facts, the canal cannot certainly be called a failure, and there is no doubt that the success of M. Lesseps has lately stimulated the old project of cutting a canal across the Isthmus of Darien, and the prospects now are that it will be accomplished. The inter-oceanic canal project has received a sudden impetus, and a delegation of Georgians was lately in Washington urging upon the President and Congress the absolute necessity and feasibility of the route and giving reasons why Congress should lend it a helping hand. This is a scheme of uniting the waters of the Ohio and Mississippi to the Atlantic Ocean by the following route: from mouth of the Tennessee river, up that stream to Guntersville, Ala.; here a narrow neck of land separates the Tennessee from the Coosa, a distance of about thirty miles; from thence up the Coosa to Rome, Ga., and at this point there is no difficulty in constructing a canal across to the Ocmulgee river, and this will open navigation to the Atlantic Ocean. The route has been ascertained by recent surveys to be eminently practicable and not very expensive, the estimated cost being less than twenty millions. The real intention in this project, of course, is to benefit the strip of country lying between the mouth of the Tennessee and Ocmulgee; as merely to reach the Atlantic, it would be much cheaper to use the present outlet, or cut a canal through to Lake Ponchartrain.

LIGHTHOUSES ON THE RIO DE LA PLATA.—The following details will be found of interest respecting the lighthouses which the Count Albert de Dax is about to have constructed upon the Rio de la Plata.

Having arranged for the erection of two lighthouses, one on the Cape Saint Marie and the other on the English Bank, General Gelly y Obes, who is associated with Count de Dax, has offered to the Governments of the Argentine Republic, and to that of Uruguay, the establisment of a general system of lighting the River de la Plata. The project has been approved by these Governments, and the protection of the eastern bank will soon be perfected by the addition of new lights.

The houses already erected, or in course of construction, are those of Saint Marie, the lights of which, upon the Fresnel system, have been shown, since the 15th of this month, to ships at the embouchure of the Grand Rio.

The pharos on the Isle of Lobos will be finished in 1873, and its beam will cross that of the Cape Saint Marie, of the east point, and of the English Bank, which will be constructed, in 1874, upon this dangerous reef; this house, with a fixed light of the first order, on the Fresnel system, will have a projection of 25 miles. This immense ray of light, which will start from a point 131 ft. above the water level, will point out the breakers in north and south channels, and will cross with the lights on the east point of the Isle de Florès, and of the Cerro de Monte Video.

The breakers, as far as Monte Video, will thus be signalled, thanks to the lights on the Isle de Florès, and of the Cerro; and if pilots follow the route to Colonia, the course will become safe, by help of the light of Bas-de-la-Panela, at present a floating station, to be changed for a fixed light of the third order, placed in an iron tower 59 ft. high. All these lighthouses will be constructed by MM. Sautter and Lemonnier, of Paris, who have already been engaged upon similar works all over the world.

ORDNANCE AND NAVAL.

LAUNCH OF THE "PENNSYLVANIA."—The following are the principal dimensions of the steamship Pennsylvania, the first ship of the American Steamship Company's Philadelphia and Liverpool Line:

Length over all, 355 ft.; length from forward part of stem to stern-post, 343 ft.; from forward part of stem to propeller, 336 ft.; beam, extreme, 43 ft.; depth of hold from top of floors to top of spar deck, 32 ft. 6 in.; hold, molded, from spar deck stringer-plate to top of keel, 33 ft. 6 in.; depth of floor-plates, 2 ft.; hold, from top of floors to top of lower deck, 16 ft. 8 in.; from top of lower deck to top of middle deck, 8 ft. 4 in.; from top of middle deck to top of spar deck, 7 ft. 6 in.; from top of keel to top of spar deck, 34 ft. 6 in. Tonnage, O.M., 3,016; capacity of coal bunkers, 720 tons. Cargo space—Middle between decks, 65,101 cubic ft., at 40 cubic ft. per ton, 1,627 tons; after hold, 24,107 cubic ft., 602 tons; forward, 42,082 cubic ft., 1,052 tons; upper between decks, 22,946 cubic ft., 573 tons; total, 154,236 cubic ft., 3,854 tons. Capacity for a cargo of compressed cotton, at 30 cubic

ft. per bale, 5,141 bales. Her draft will not exceed 20 ft. 6 in. in fresh water, with coal bunkers full, and a dead-weight cargo of 1,740 tons (2,240 lbs.) or a measurement cargo of 3,854 tons (40 cubic ft.), also a full complement of saloon and steerage passengers, officers and crew, all necessary stores and outfit on board. Her draft is not to be less than 19 ft. 6 in.

The hull and appendages have been built and fitted out in accordance with English Lloyd's Register, in addition to which the main or middle deck has under its 4 in. yellow pine plank a deck of 5-16 iron for two-thirds of the length of the vessel, securely fastened to the stringer-plates and deck-beams.

Passenger accommodation is provided for 76 in the saloon, which will be fitted in a style of extreme elegance. The steerage will afford ample room and comfortable accomodation for 854. The average contract speed is to be 11½ knots on an average consumption of 40 tons (2,240 lbs.) of coal in 24 hours.

The Pennsylvania is brig-rigged, with masts 54 and 58 ft. above spar deck, with topmasts 31, 16 and 10 ft.; yards, 63, 47 and 34 ft. All the standing rigging is of wire, of proper size; running rig of manilla, fitted with all suitable sails and tackling necessary for the North Atlantic service.

The materials entering into the construction of hull, boilers and engines, the joiner-work and outfit, is, as far as possible, of American manufacture. —*Nautical Gazette.*

IRON STEAM SHIPBUILDING ON THE CLYDE.—The really commercial introduction of steam navigation in Europe was due to Mr. Henry Bell, of Helensburgh, who, on the 18th of January, 1812, completed the Comet. We are indebted to Captain Ericsson for the first complete screw steamer, which he accomplished in 1837. The first steamer built of iron on the Clyde was the Aglaia, which was launched in the year 1827, and which plied on the Loch Eck, *en route* to Inverary. The Fairy Queen, of 39 tons, was the first iron steamer, which plied on the Clyde in 1831. This vessel was constructed at the Canal Basin Foundry—a mile and half from the harbor of Glasgow—and launched into the Clyde. She was propelled by an oscillating engine, probably the first application of this form of engine to marine purposes. The first iron screw steamer was the Fire Queen, of 135 tons and 80 horse power, built in 1845. The first steamer which plied between Glasgow and New York was the City of Glasgow. The Royal Sovereign—of 447 tons—built in 1839, was the first paddle steamer of iron which plied between Glasgow and Liverpool. An iron sailing vessel, built in 1842, plied between Glasgow and Rotterdam *via* the Forth and Clyde Canal. As an illustration of our day of small things in shipping, it is stated the arrivals of vessels at the Broomielaw for the month of July, 1767, of which there were 22 in all, were as follows: six vessels of 2 tons each, five of 10 tons, four of 15 tons, two of 18 tons, one of 25 tons, and three of 35 tons—in all, 318 tons. The revenue of Clyde Trust, for river and harbor dues, in the same year, was £1,975, while for 1871 it amounted to £164,188. The Customs revenue collected at Glasgow for 1787 was £370, while, for the past ten years, it had averaged over a million for each year. From the year 1812 to 1822, inclusive, there were built on the Clyde 48 steamers, the hulls being of wood. Of these the Dumbarton Castle—of 81 tons and 32 horse-power—was built in 1815; and was the first to attempt to extend the trip to Rothesay. The trip was successful; and was considered so extraordinary a feat that the captain (James Johnston) was presented with an elegantly polished, painted, and gilt punch-bowl, in commemoration of the event. The Britannia—73 tons and 28 horse-power—was built in 1815; and made a pleasure excursion to the Giant's Causeway and Londonderry, which, at the time, was considered a great risk. But, being successful, it led to the trade with Londonderry. The Rob Roy, built by Mr. D. Napier in 1818, of 56 tons and of 30 horse-power, was the first seagoing steamer in Europe; it was at once put on the station between Glasgow and Belfast, and proved very successful. —*Engineer.*

BOOK NOTICES.

THE STRAINS IN TRUSSES COMPUTED BY MEANS OF DIAGRAMS. By F. A. RANKEN, M. A. London: Longmans. For sale by Van Nostrand.

The system of exhibiting by means of diagrams the relative strains to which the several parts of a piece of framework are subjected when the whole is loaded with a weight, was propounded a few years ago by Professor Clerk Maxwell. This work will greatly aid those unacquainted with the method, in applying it to various kinds of structures, such as trussed roofs and bridges. The author makes no claim to be the inventor of the system, but only "to set in a clear light the theory and method of computing by diagrams the strains in trusses bearing a constant load," so that "it may be found intelligible even by those who have no previous knowledge of statics." He commences his treatise with an explanation of the mode in which forces are considered in statics, the principle of resultants and components, together with the parallelogram. The author has omitted to demonstrate the steps by which the principles enunciated can be reduced to the system of stress diagrams for triangular or polygonal trusses.

After giving several examples of the balancing of three forces to familiarize the student with the method of forming diagrams, he proceeds with the application to the ordinary forms of roof trusses, beginning with the king-post truss, and proceeding with more elaborate combinations of framework. Taking 12 to represent the load sustained by each truss, he finds by means of the diagram what portion of that quantity is borne by each part, and whether the strain is tensile or compressive; he assumes that, if a continuous beam is loaded uniformly, and supported in the centre as well as at each end, the weight borne by the middle prop is twice the weight supported by each of the abutments, and when there are two equidistant props that each has one-third of the load to carry, the two abutments carrying the other third between them, and so on.

In the examples given in the treatise the strain on the king or queen post from the weight of the tie-beam is omitted "for simplicity;" but if there is a ceiling to be supported by the tie-beam this would produce one of the most important strains

which the truss would have to bear, and ought not in any case to be neglected, the chief business of the king or queen post being to prevent the sagging of the tie-beam.

The effect of the wind is by far the most important of the strains which a roof-truss has to sustain, and this is taken by Mr. Ranken in all the examples as a dead weight acting equally on both sides of the roof at the same time; except, however, in roofs of very low pitch, this would lead to very inaccurate results, as the force of the wind is almost always sustained by one side much more than the other, so as to produce a racking strain upon the framework; to counteract which the timbers must be made much stronger than if they had only to sustain a uniform vertical weight acting on both sides alike. The stress diagrams ought, therefore, to be always drawn on the hypothesis of the wind being at right-angles to one surface of the roof, and the figures will then have a very different appearance to those given by the author.

A considerable number of examples are fully worked out for the frameworks of girder bridges as well as of roofs, by mastering which, the student will find that he has acquired great facility in the application of the principle to practical purposes without having to trouble himself about algebraical or trigonometrical formulas; these latter, however, cannot be dispensed with in considering trusses exposed to the action of a travelling load, as in railway bridges, to which this system of diagrams is hardly applicable. In applying the method to practical uses, care should always be taken to ascertain the exact mode in which the strains to be supported are applied, as otherwise very erroneous results will be obtained, by which the system may get into disrepute, whereas the mode of using it is really in fault.

The system of computing strains in trusses by means of diagrams has hitherto been too little known or practised by engineers, and the present work, although not so accurate as might have been desired, will do good service for the profession by showing how easy it is in application after a little practice.—*Builder.*

IRON AS A MATERIAL OF CONSTRUCTION: A HANDBOOK FOR THE USE OF STUDENTS IN ENGINEERING.—By WILLIAM POLE, F.R.S., M.I. C.E., etc. London: E. and F. N. Spon, Charing Cross. For sale by Van Nostrand.

The constantly increasing application of iron to constructive purposes attaches importance to every effort made to enable the engineering student to become acquainted with the leading properties of the material, and the most ready means of ascertaining its quality and value for any particular use to which it is to be applied; and since the volume just issued under this title comprises the substance of a course of lectures, delivered by Professor Pole, F.R.S., at the Royal School of Naval Architecture, South Kensington, revised and enlarged to form a handbook for the use of students in engineering, its practical value will be readily estimated. The Professor very truly remarks that it is questionable whether the substitution of iron for stone, brick, etc., as a material of construction, is not being carried too far, and whether the new perishable substance is not frequently adopted for the sake of cheapness or facility of construction in cases where the more durable but less tractable material, stone, would be more appropriate, more noble, and more worthy of the profession; but as iron is now the favorite material, the chief consideration is how to use it most advantageously. In the present volume Prof. Pole has confined himself to practical facts almost exclusively, having only introduced such theoretical matter as is necessary to explain the bearing of the facts given and to guide their practical application.

Referring to the manufacture of pig iron, he supplies an outline of the operations which go on in the blast-furnace, and in some cases furnishes the French or German equivalents for the English technical terms; for instance, he suggests that the name *boshes* is probably a corruption of the German *bauch*, and that *tuyaux* is the French equivalent for *tuyere*. He gives a short historical notice of some of the prominent inventions connected with the iron manufacture, and concludes his chapter with a few statistics. The production of malleable iron is dealt with in the next chapter, after which the Professor treats of the mechanical properties of iron generally. In referring to cast iron he affords some very useful information; he tells us that it is not all pig iron that is fit for making castings, for pig iron is also used for the manufacture of malleable iron, and the qualities made for the two purposes are quite distinct from each other. The process of melting the pig and casting it into the required shapes is called iron founding (from the French *fondre*, to melt), the place where it is done is an iron foundry, and the person who does it is an iron founder. The first duty of the founder will be to determine what kind of iron he will use to make his castings, and in this he will be guided by the nature of the object to be made, and the purposes it is to serve. He devotes a chapter to the general properties of wrought iron, so that the engineer who carefully studies the book will be well able to comprehend the process by which iron is manufactured, and the method by which its strength is usually tested. Prof. Pole states that he claims no originality or novelty in the scientific treatment of the subject, and that the experimental data are due to the various authorities whose names are attached to them; consequently, the engineering student who consults the book may place complete reliance upon the facts given. Regarding the book as a whole, it cannot be questioned that Prof. Pole has brought together a large amount of information in the volume itself, and by his judicious reference to authorities he has afforded the utmost facilities to those who desire to give especial attention to any particular branch of the subject.

SOLID GEOMETRY AND CONIC SECTIONS. WITH APPENDICES ON TRANSVERSALS AND HARMONIC DIVISION. FOR THE USE OF SCHOOLS. —By J. M. WILSON, M.A., late Fellow of St. John's College, Cambridge, and Mathematical Master of Rugby School. London: Macmillan and Co. 1872.—For sale by D. Van Nostrand.

The study of solid geometry comprises one of those branches of knowledge with which even those who have received a liberal eduction are but very indifferently acquainted. It is exactly one of those subjects which are never thoroughly acquired except by those who have a decided taste for mathematical analysis and investigation. It is true that boys at school learn by rote some twenty

propositions of the eleventh book of Euclid, and are in consequence supposed to know something about solid geometry. The truth is, that they really learn nothing, and, were it possible, understand less. We have often expressed our opinion respecting the unsuitability of Euclid's treatise on geometry as a text-book for ordinary students in the present age, and shall not, therefore, dwell on the subject. There is not the least doubt that the use of so obsolete a mode of instruction has gone far to prevent the dissemination of a knowledge in which, as is well known, our continental neighbors are greatly our superiors. This superiority abroad is, in all probability, partly owing to the adoption of a more modern, more attractive, and more practical method of instruction. At present the path of knowledge has been rendered very much smoother, and more accessible than formerly, and one can scarcely expect a person to select an unpleasant road when an agreeable one leading to the same goal is equally at his service.

Our author commences with a chapter on "Planes," and gives clear enunciations and solutions of the various problems connected therewith, and then proceeds to the different figures which are formed by their combination. A chapter on "Conic Sections" brings his useful little treatise to a close. A very valuable feature in the work is the addition of a series of questions in the shape of "Exercises" to each separate chapter. The student, after mastering any given rule or proposition, is naturally anxious to test his ability to apply what he has learned to an example. If none are afforded by the text-book he must search for them elsewhere, and the result generally is that he finds none, and remains content with a mere theoretical acquaintance with the subject—an acquaintance which is often of a very transitory description. The contents of this little work are printed on toned paper, and altogether it forms a handy compendium of the subject.—*Engineer.*

RAILWAYS OR NO RAILWAYS: Narrow Gauge Economy with Efficiency *v.* Broad Gauge Costliness with Extravagance. By ROBERT F. FAIRLIE. (London: Effingham Wilson. 1872.) For sale by Van Nostrand.

In this well-printed volume of 148 pages, Mr. Fairlie undertakes the defence of the modifications of the railway system which are associated with his name. The merits of the narrow gauge and of the Fairlie engine have recently been fully discussed; it would be out of place here to reopen the question or to discuss the contents of this volume, further than by stating its general scope and the nature of the circumstances which called for its appearance.

The author states, that in India and Australia the broad gauge is worse than a mistake. In England it bars true railway progress. "In the United States, on the other hand, the case is widely different; opinion finds free vent among the members of the profession, and with the greatest earnestness, and with much ability, the merits of both sides of the case have been universally discussed; while thousands of miles of narrow-gauge line have been commenced, which, when completed, will practically and thoroughly decide the now much-vexed question." Mr. Fairlie takes advantage of the opportunity afforded by the document recently published by the Hon. S. Seymour, of New York, upon the question of narrow-gauge railways in answer to a report prepared by General G. P. Buell, chief engineer of the Texas Pacific Railroad, advocating the adoption of a 3 ft. 6 in. gauge for a great trunk line of 1,500 miles in length. But as this review may be regarded as representative, expressing the opinions of narrow-gauge antagonists, our author has analyzed it thoroughly.

The question discussed by both sides is not merely a mechanical one, but rather, what width of gauge is the best adapted to admit of such a construction of machinery as will more profitably overcome the resistance of the line, and that will meet the nature and extent of the traffic present and prospective. The work is written by a most competent authority on a question of vast interest to engineers, capitalists, and traders, and even to all who have an interest in the prosperity of the great railway enterprises of the earth.—*Mechanics' Magazine.*

A HAND-BOOK OF CHEMICAL TECHNOLOGY. By RUDOLF WAGNER, Ph. D. Translated and edited by WILLIAM CROOKES, F. R. S. London: J. & A. Churchill. For sale by Van Nostrand.

In a volume containing some 750 pages, with numerous illustrations, the methods of preparing and working the various metals and their salts by the latest improved processes are described under the head of metallurgical chemistry, together with the application of the voltaic current to electro-metallurgy. Manufactures of such importance as the preparation of potash and soda salts, bleaching-powder, sulphuric acid, and the methods employed in recovering all that is of value from "waste" solutions and "rubbish" heaps, occupy prominent places. The manufacture of soap, glass, lime, stoneware, mortars, the technology of vegetable fibres, including paper-making, and the arts of brewing, distillation, dyeing, and others, all will be found explained in a necessarily concise yet ample manner. The subjects enumerated form but a portion of the contents of this book, which must be valuable to the manufacturer and the student. It has been fully appreciated in Germany; the edition of which the present book is the English translation is the eighth, the first having been published in 1850. Mr. Crookes has edited the work carefully; all the improvements introduced since the publication of the German edition have been added, and the whole of the formulæ, which are molecular throughout, have been revised.

SEWER GAS, AND HOW TO KEEP IT OUT OF HOUSES. By O. REYNOLDS, M. A., Professor of Engineering, Owens College, Manchester., etc. (London: Macmillan. 1872.) For sale by Van Nostrand.

The accomplished writer has done a very sensible thing. While the principal part of this book was written four years ago, it has been kept back till the suggestions it contains should have a thorough practical trial, and it is now published to help people who are in doubt and trouble about the drainage of their houses. "What appears to be wanted is a book of approved scientific merit, and of such a practical character that a householder or any unscientific person can learn from it how to

ascertain if drains are safe, and if not, how to get them put right. In the absence of such a work, I venture to think that this little book will be useful."

The author's object was to suggest a plan for preventing the evil of the back flow of gas into our houses. Of this plan he has had four years' experience; and has, without exception, found it to answer perfectly. Professor Reynolds is not aware that this complete scheme has ever been suggested before; but it embodies as its principal features several plans which are daily growing in favor; among which, perhaps, the most important is that of having a break or trough in the pipe which connects the house with the sewer. This has now been advocated for several years, though the name of its first proposer seems to be unknown.—*Mechanics' Magazine.*

AN ELEMENTARY TREATISE ON CURVE TRACING. By PERCEVAL FROST, M. A., Mathematical Lecturer of King's College. (London: Macmillan & Co. 1872.) For sale by Van Nostrand.

This is a preliminary treatise on the properties of curves. The author says he supposes himself to be instructing a student whose reading has been confined to very narrow limits. Regarded as a special preparation for a special subject, it may be considered useful in giving clear ideas when the student enters upon the systematic treatment of the properties of curves; especially since the classification of curves according to degrees, and the subdivision of curves of the same degree into species, are now being taken in hand by some eminent mathematicians.

KNIGHT'S AMERICAN MECHANICAL DICTIONARY. By EDWARD H. KNIGHT. New York: J. B. Ford & Co.

The first number of this Dictionary is at hand. It is a handsome quarto of 108 pages, and includes a description of tools, instruments, machines, processes and inventions—general technological vocabulary. To be illustrated with five thousand engravings. The present number contains valuable descriptions of various forms of air engines. The typography and cuts are unexceptionable.

MISCELLANEOUS.

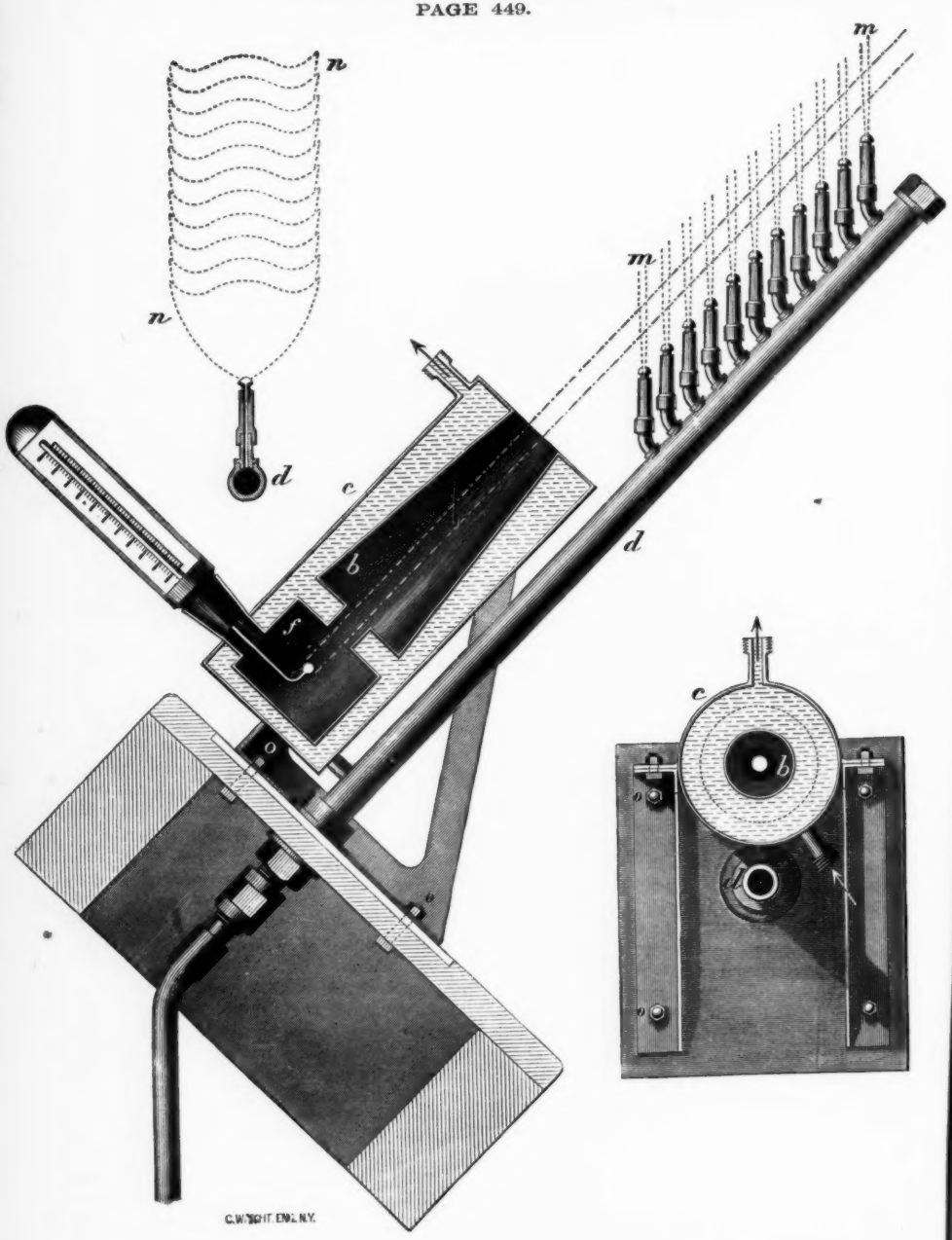
COLORING VENEERS.—Some manufacturers of Germany who had been supplied from Paris with veneers colored throughout their mass, were necessitated by the late war to produce them themselves. Experiments in this direction gave in the beginning colors fixed only on the outside, while the inside was untouched, until the veneers were soaked for twenty-four hours in a solution of caustic soda, containing ten per cent. of soda, and boiled therein for half an hour; after washing them with sufficient water to remove the alkali, they may be dyed throughout their mass. This treatment with soda effects a general disintegration of the wood, whereby it becomes in the moist state elastic and leather-like, and ready to absorb the color; it must then, after dyeing, be dried between sheets of paper, and subjected to pressure, to retain its shape. Veneers treated in this way, and left for twenty-four hours in a hot decoction of log-wood (one part of log-wood to three of decoction), removing them after the lapse of that time, and, after drying them superficially, putting them into a hot solution of copperas (one part of copperas to thirty of water), will, after twenty-four hours, become beautifully and completely dyed black. A solution of one part of picric acid in sixty of water, with the addition of so much ammonia as to become perceptible to the nose, dyes the veneers yellow, which color is not in the least affected by subsequent varnishing. Coralline dissolved in hot water, to which a little caustic soda and one-fifth of its volume of soluble glass has been added, produces rose colors of different shades, dependent on the amount of coralline taken. The only color which veneers will take up, without previous treatment of soda, is silver gray, produced by soaking them for a day in a solution of copperas (one of copperas to one hundred of water.

NEW CASE HARDENING PROCESS.—A resident of Montreal has recently patented in the United States a new process of carbonizing wrought-iron articles. Charcoal, coal dust, oil, bone dust, have each been used for this purpose; but strangely enough, one of the most highly carbonized substances, and one most easily accessible to an iron worker, has been overlooked. This is molten cast iron, and the inventor prepares a bath of it, having previously eliminated any phosphorus and sulphur it may contain. Spiegeleisen is especially recommended for the purpose; but good malleable iron, melted in a cupola with charcoal, anthracite or bituminous coal, or coke, will serve the purpose. Crucibles for melting small quantities, or reverberatory furnaces for large masses, may be employed. The cast iron readily yields its carbon to the immersed articles, and this element would rapidly become exhausted if no means are taken to continue a supply. To obviate this, the crucibles and furnaces are lined with a coating of charcoal powder or of plumbago with which nitrogenous matter has been incorporated. Leather or horn shavings will do for this purpose. If the process were carried out on a large scale, the cast iron from which the carbon had been eliminated could be at once sent to the rollers and made into bar iron, another melting being used for a second case hardening operation; and many other changes of detail will probably suggest themselves to our practical readers.

NEW ZEALAND COAL.—Coal has been discovered at Whangaparona in the north of the province of Auckland, and from the trials made it is said to be of good quality. The extent of the bed, too, is thought to be large. At the Bay of Islands mines water still has the upper hand, and but little coal can be supplied from the mines for some time to come.

POPULATION OF BOMBAY.—The exact population of Bombay on the 21st of February, when a census was taken, has been ascertained to be 646,636 persons. This total includes the harbor population.

INSTRUMENT FOR MEASURING RADIANT HEAT.

Constructed by CAPTAIN JOHN ERICSSON.

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